Cimarex Energy Co.
202 S. Cheyenne Ave.
Suite 1000
Tulsa, Oklahoma 74103-4346
PHONE 918.560.7257
FAX 539.777.0501

Stuart Wittenbach
ES&H Director

CIMAREX

Certified Mail (9407110898765043007441)

August 27, 2019

Eddie Terrill, Director, Air Quality
Oklahoma Department of Environmental Quality
Air Quality Division
P.O. Box 1677
Oklahoma City, Oklahoma 73101-1677

Re: 40 CFR 60 Subpart OOOOa, 30-day Advance Notification to Conduct Performance Test
Cimarex Energy Co.: Lehman BIA 2-11H (2018-1177-O), Lehman Com 7-11H (2018-1031-O)
Blaine County, Oklahoma

Dear Mr. Terrill:

Pursuant to 40 CFR §60.8(d), Cimarex Energy Co. (Cimarex) is hereby providing 30-day advance notification of intent to conduct a performance test to afford the agency an opportunity to have an observer present. Cimarex proposes to conduct performance tests on or about the week of October 7, 2019.

Cimarex proposes to conduct performance tests on two (2) enclosed combustors located at the facilities referenced above. The performance tests will be conducted in accordance with the requirements of 40 CFR 60 Subpart OOOOa. Please find enclosed the testing protocols for these devices.

Should you or members of your staff have any questions or require additional information, please contact me at (918)560-7257 or via email at swittenbach@cimarex.com.

Sincerely,
Cimarex Energy Co.

Stuart Wittenbach
ES&H Director

Enclosures (2) – 40 CFR 60 Subpart OOOOa Sampling Plans

cc: Joe Hull, Cana Production Division Manager, Cimarex Energy Co., Tulsa, OK
Dwayne Ricks, Cana Production Superintendent, Cimarex Energy Co., Hinton, OK
Air Quality Library File: (CAOK Testing Notification)

AIR HYGIENE, INC.

Testing Solutions for a Better World

40 CFR 60, SUBPART OOOOa
EMISSIONS TESTING PROTOCOL

FOR
ONE ENCLOSED COMBUSTOR

PREPARED FOR
CIMAREX

AT THE
LEHMAN BIA 2-11H FACILITY
WATONGA, OKLAHOMA

Oklahoma Department of Environmental Quality
Permit No: 2018-1177-O
Source Classification Code (SCC): 31000205

August 15, 2019

Corporate Headquarters
1600 W Tacoma Street
Broken Arrow, OK 74012

AIR HYGIENE, INC.

(918) 307-8865 or (888) 461-8778
www.airhygiene.com

Remote Testing Offices
Las Vegas, NV 89156
Ft. Worth, TX 76028
Humble, TX 77338
Shreveport, LA 71115
Miami, FL 33101
Pittsburgh, PA 15205

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August 15, 2019

Prepared By:

Nathan Arthur, QSTI, Sr. Manager – Test Protocols

rev - 0

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Table of Contents

1.0 INTRODUCTION

1.1 General Facility Description

Cimarex (Cimarex) owns and operates the Lehman BIA 2-11H facility located in Blaine County, Oklahoma. Located on the facility is one Enclosed Combustor, designated as Combustor 1. The interest of this protocol is Combustor 1.

The Combustor 1 stack is vertical, circular in orientation. The test port locations meet the minimum EPA Method 1 requirement of at least 0.5 duct diameters (dd) upstream and 2.0 dd downstream from the nearest disturbances. All stack dimension measurements will be taken and verified in the field prior to the beginning of testing.

1.2 Reason for Testing

The unit is subject to emission testing requirements set forth in the standards designated by the United States Environmental Protection Agency (EPA) Title 40, Code of Federal Regulations, Part 60 (40CFR60), Subpart OOOOa and the Oklahoma Department of Environmental Quality (ODEQ) operating permit (2018-1177-O); and to the limits specified in Table 1.2. As such, the unit will be tested for total organic compounds (TOC), moisture (H_2O), and oxygen (O_2) with the unit operating at the maximum combustion rate (MCR).

TABLE 1.2
EMISSION LIMITS

Target	Permit Limits
TOC	275 ppmvw@3%O_2

2.0 SUMMARY

2.1 Site Information

Site:	Cimarex Watonga Facility
Contact Person:	Marcia Ortiz
Office:	(918) 560-7290
Cell:	(918) 805-6330
Email:	MOrtiz@cimarex.com
Latitude, Longitude:	35.7836921, -98.3459254

2.2 Test Contractor Information

Company:	Air Hygiene International, Inc.
Contact Person:	Danny Parr, Director of Operations
Mailing Address:	1600 W Tacoma Street Broken Arrow, Oklahoma 74012
Office:	(918) 307-8865
Cell:	(918) 809-8947
Fax:	(918) 307-9131
E-mail:	danny@airhygiene.com
Website:	www.airhygiene.com
AETB Certificate No:	3796.02
ISO/IEC Certificate No:	3796.01

2.3 Expected Test Start Date

Testing is anticipated to begin on October 8, 2019. Notification of changes will be made by Cimarex, as necessary.

2.4 Testing Schedule

The following schedule indicates specific activities required to be done each day; however, the schedule may require flexibility and will be compacted or extended as necessary.

Pre-test Activities	**Due Date**
1. Prepare draft test protocol (Air Hygiene)	prior to testing

On-site Activities	**Time**
Day 0 – Initial site mobilization, setup	
• Arrive at site and attend safety training	08:00 – 09:00
• Setup on Combustor 1	09:00 – 12:00
• Conduct preliminary testing of Air Hygiene equipment	12:00 – 16:00

Compliance Testing	**Time**
Day 1 – Combustor 1	
• Daily setup and calibrations	07:00 – 08:00
• Conduct testing for TOC and O_2 • TOC and O_2 testing: 3, 60-minute runs	08:00 – 12:00
• Teardown and move to next facility and setup on Combustor 2	12:00 – 14:00

Activities after Testing

- Demobilization of Testing Crew (Air Hygiene) — Day 1
- Preparation of draft test report (Air Hygiene) — Days 2 – 9
- Submit for review to Cimarex (Air Hygiene) — Day 10
- Review and comment on draft (Cimarex) — Days 11 – 15
- Prepare final hard copy test reports (Air Hygiene) — Days 16 – 19
- Final reports delivered to Cimarex (Air Hygiene) — Day 20

2.5 Test Report Content

The Test Report for the unit will meet the requirements of the ODEQ and the EPA for compliance and certification testing. The report will include discussion of the following:

- Introduction
- Plant and Sampling Location Description
- Summary and Discussion of Test Results Relative to Acceptance Criteria
- Sampling and Analytical Procedures
- QA/QC Activities
- Test Results and Related Calculations
- Stack and Testing Equipment Drawings
- Raw Field Data and Calibration Data Sheets
- Sampling Log and Chain-of-Custody Records
- Audit Data Sheets

2.6 Equipment and Procedures

Test methods and parameters to satisfy 40 Code of Federal Regulations (CFR) Part 60 and will include:

- 40 CFR 60, App A, EPA Method 1 for sample location
- 40 CFR 60, App A, EPA Method 3A for oxygen (O_2)
- 40 CFR 60, App A, EPA Method 25A for total hydrocarbons (TOCs)

2.7 Proposed Variations

TOC testing will be conducted from a single point near the center of the stack. No pre-test stratification test will be conducted.

No bias correction will be utilized for the EPA Method 25a sampling and all negative readings will be replaced with "zeroes" prior to determining final averages. Also, the TOC analyzer will be calibrated by running the certified gases through the sample probe, rather than directly to the back of the analyzer.

2.8 Compliance Sampling Strategy

Testing will be conducted on the unit for total organic compounds (TOC) and oxygen (O_2) with the unit operating at the maximum combustion rate (MCR).

Testing on the combustors will include:

- TOCs – 3 test runs at 1 hour per run
- O_2 – 3 test runs at 3 hours per run

During testing Cimarex personnel will track relevant unit operating parameters. Air Hygiene personnel will monitor and record ambient temperature (°F), relative humidity (%), and barometric pressure (in. Hg) at the start of each test run.

Method 3A and 25A – Oxygen and Total Organic Compound Testing
Refer to Appendix B for additional details.

APPENDIX A

QA/QC PROGRAM

QA/QC PROGRAM

AIR HYGIENE ensures the quality and validity of its emission measurement and reporting procedures through a rigorous quality assurance (QA) program. The program is developed and administered by an internal QA team and encompasses six major areas:

1. Field Qualifications
2. QA reviews of reports, laboratory work, and field testing;
3. Equipment calibration and maintenance;
4. Chain-of-custody;
5. Training; and
6. Knowledge of current test methods

Field Qualifications

Air Hygiene personnel are required to gain and maintain competence with testing methods and techniques according to their job titles and the roles they play during field testing events. Qualifications for each job description include:

Staff Technician - An entry level position with responsibility to test on the stack by performing duties that include: keep trucks and trailers stocked and clean, travel to and from job site, be the "hands of the test" on the stack; stay on a stack during the sample test, set up and tear down equipment on-site, perform maintenance on equipment in the shop and on-site.

Test Technician or Specialist - Acts as the "hands of the test" on the stack by performing duties that include: stay on a stack during the sample test, migrate to the testing trailer and learn the different analyzers and testing methods used on site, set up and tear down testing equipment on site, learn the system for testing from Testing Managers and Project Managers, travel to and from job site; including driving responsibilities under DOT requirements, follow directions of Testing Managers and Project Managers, learn the proper way to conduct on-site test of stationary stacks

Test Manager or Engineer - Directs and coordinates all aspects of a successful test by performing the following duties personally or through subordinate supervisors including: operating analyzers and consoles during testing along with QA/QC procedures, supervise set up and tear down of equipment on site, writing, reviewing, and revising final test reports, working with the client or state personnel while on the job site, managing pre-test checklists and onsite testing procedures, diagnose and repair any problems that may arise with the equipment, safely operate a man lift and drive a truck with or without a trailer, act as crew leader in the field, write protocols and reports, maintain project log of services performed on the job, verify all equipment needed for a job was loaded on the trailer. Test Managers must hold as least one QSTI certificate.

Project Manager - Directs and coordinates all aspects of a successful test by performing the following duties personally or through subordinate supervisors including: operating analyzers and consoles during testing along with QA/QC procedures, supervise set up and tear down of equipment on site, writing, reviewing, and revising final test reports, working with the client or state personnel while on the job site, managing pre-test checklists and onsite testing procedures, diagnose and repair any problems that may arise with the equipment, safely operate a man lift and drive a truck with or without a trailer, act as crew leader in the field, write protocols and reports, maintain project log of services performed on the job, verify all equipment needed for a job was loaded on the trailer. Project Managers typically hold QSTI certificates in Groups 1 through 4.

QA Reviews

AIR HYGIENE's review procedure includes a review of each source test report, along with laboratory and fieldwork by the QA Team.

The most important review is the one that takes place before a test program begins. The QA Team works closely with technical division personnel to prepare and review test protocols. Test protocol review includes selection of appropriate test procedures, evaluation of interferences or other restrictions that might preclude use of standard test procedures, and evaluation and/or development of alternate procedures.

Equipment Calibration and Maintenance

The equipment used to conduct the emission measurements is maintained according to the manufacturer's instructions to ensure proper operation. In addition to the maintenance program, calibrations are carried out on each measurement device according to the schedule outlined by the Environmental Protection Agency. Quality control checks are also conducted in the field for each test program.

Chain-of-Custody

AIR HYGIENE maintains full chain-of-custody documentation on all samples and data sheets. In addition to normal documentation of changes between field sample custodians, laboratory personnel, and field test personnel, AIR HYGIENE documents every individual who handles any test component in the field (e.g., probe wash, impinger loading and recovery, filter loading and recovery, etc.). Samples are stored in a locked area to which only AIR HYGIENE personnel have access. Field data sheets are secured at AIR HYGIENE's offices upon return from the field. Per standard Air Hygiene policy, laboratory samples will be discarded after 30 days of receipt of final report unless otherwise specified in writing.

Training

Personnel training is essential to ensure quality testing. AIR HYGIENE has formal and informal training programs, which include:

1. Attendance at EPA-sponsored training courses;
2. Enrollment in EPA correspondence courses;
3. A requirement for all technicians to read and understand Air Hygiene Incorporated's QA manual;
4. In-house training and QA meetings on a regular basis; and
5. Maintenance of training records.

Knowledge of Current Test Methods

With the constant updating of standard test methods and the wide variety of emerging test procedures, it is essential that any qualified source tester keep abreast of new developments. AIR HYGIENE subscribes to services, which provide updates on EPA reference methods, rules, and regulations. Additionally, source test personnel regularly attend and present papers at testing and emission-related seminars and conferences.

COMBUSTION TESTING QUALITY ASSURANCE ACTIVITIES

A number of quality assurance activities are undertaken before, during, and after each testing project. The following paragraphs detail the quality control techniques, which are rigorously followed during testing projects.

Each instrument's response will be checked and adjusted in the field prior to the collection of data via multi-point calibration. The instrument's linearity will be checked by first adjusting its zero and span responses to zero nitrogen and an upscale calibration gas in the range of the expected concentrations. The instrument response will then be challenged with other calibration gases of known concentration and accepted as being linear if the response of the other calibration gases agrees within plus or minus 2 percent of range of the predicted values.

After each test run, the analyzers will be checked for zero and span drift. This allowed each test run to be bracketed by calibrations and documents the precision of the data just collected. The criteria for acceptable data are that the instrument drift is no more than 3 percent of the full-scale response. Quality assurance worksheets will be prepared to document the multipoint calibration checks and zero to span checks performed during the tests.

The sampling systems will be leak checked by demonstrating that a vacuum greater than 10 in Hg can be held for at least 1 minute with a decline of less than 1 in. Hg. A leak test will be conducted after the sample system is set up and before the system is dismantled. This test will be conducted to ensure that ambient air has not diluted the sample. Any leakage detected prior to the tests will be repaired and another leak check conducted before testing commences.

The absence of leaks in the sampling system will also be verified by a sampling system bias check. The sampling system's integrity will be tested by comparing the responses of the analyzers to the calibration gases introduced via two paths. The first path will be directly into the analyzer and the second path will be via the sample system at the sample probe. Any difference in the instrument responses by these two methods will be attributed to sampling system bias or leakage. The criteria for acceptance will be agreement within 5 percent of the span of the analyzer.

The control gases used to calibrate the instruments will be analyzed and certified by the compressed gas vendors to ± 1% accuracy for all gases. EPA Protocol No. 1 will be used where applicable to assign the concentration values traceable to the National Institute of Standards and Technology (NIST), Standard Reference Materials.

AIR HYGIENE maintains a large variety of calibration gases to allow the flexibility to accurately test emissions over a wide range of concentrations.

APPENDIX B

TEST EQUIPMENT CONFIGURATION AND DESCRIPTION

INSTRUMENT CONFIGURATION AND OPERATIONS FOR GAS ANALYSIS

The sampling and analysis procedures to be used conform with the methods outlined in the Code of Federal Regulations, Title 40, Part 60, Appendix A, Methods 1, 3A, and 25A.

The sample system to be used for the real-time gas analyzer tests is configured per the following description. A stainless steel probe will be inserted near the center of the stack. The gas sample will be continuously pulled through the probe and transported via 3/8-inch heat-traced Teflon® tubing to a stainless steel, minimum-contact condenser designed to dry the sample and then through Teflon® tubing via a stainless steel/Teflon® diaphragm pump and into the sample manifold within the mobile laboratory. From the manifold, the sample is partitioned to the real-time gas analyzer through rotameters that control the flow rate of the sample. Exhaust samples are routed to the wet based analyzer prior to gas conditioning.

The schematic (Figure 1) shows that the sample system is also equipped with a separate path through which a calibration gas could be delivered to the probe and back through the entire sampling system. This allows for convenient performance of system bias checks as required by the testing methods.

All instruments are housed in an air-conditioned, trailer-mounted mobile laboratory. Gaseous calibration standards are provided in aluminum cylinders with the concentrations certified by the vendor according to EPA Protocol No. 1.

This general schematic also illustrates the analyzers to be used for the tests (i.e., O_2). All data from the Reference Method continuous monitoring instruments are recorded on a Logic Beach Hyperlogger. The Hyperlogger retrieves calibrated emissions data from each instrument every second. An average value is recorded every 30 seconds.

The stack gas analysis for O_2 concentrations will be performed in accordance with procedures set forth in EPA Method 3A. The O_2 analyzer uses a paramagnetic cell detector.

TOC emission concentrations will be quantified in accordance with principles set forth in EPA Method 25a. A flame ionization detector FID will be used for the measurements. This detector responds to all hydrocarbons in the sample. Total hydrocarbon results will be assumed as TOCs.

E:\SHARED\DRAWINGS\EMISSIONS TESTING LAB.PPT 04/18/08 DRAWING:08-001 TKG

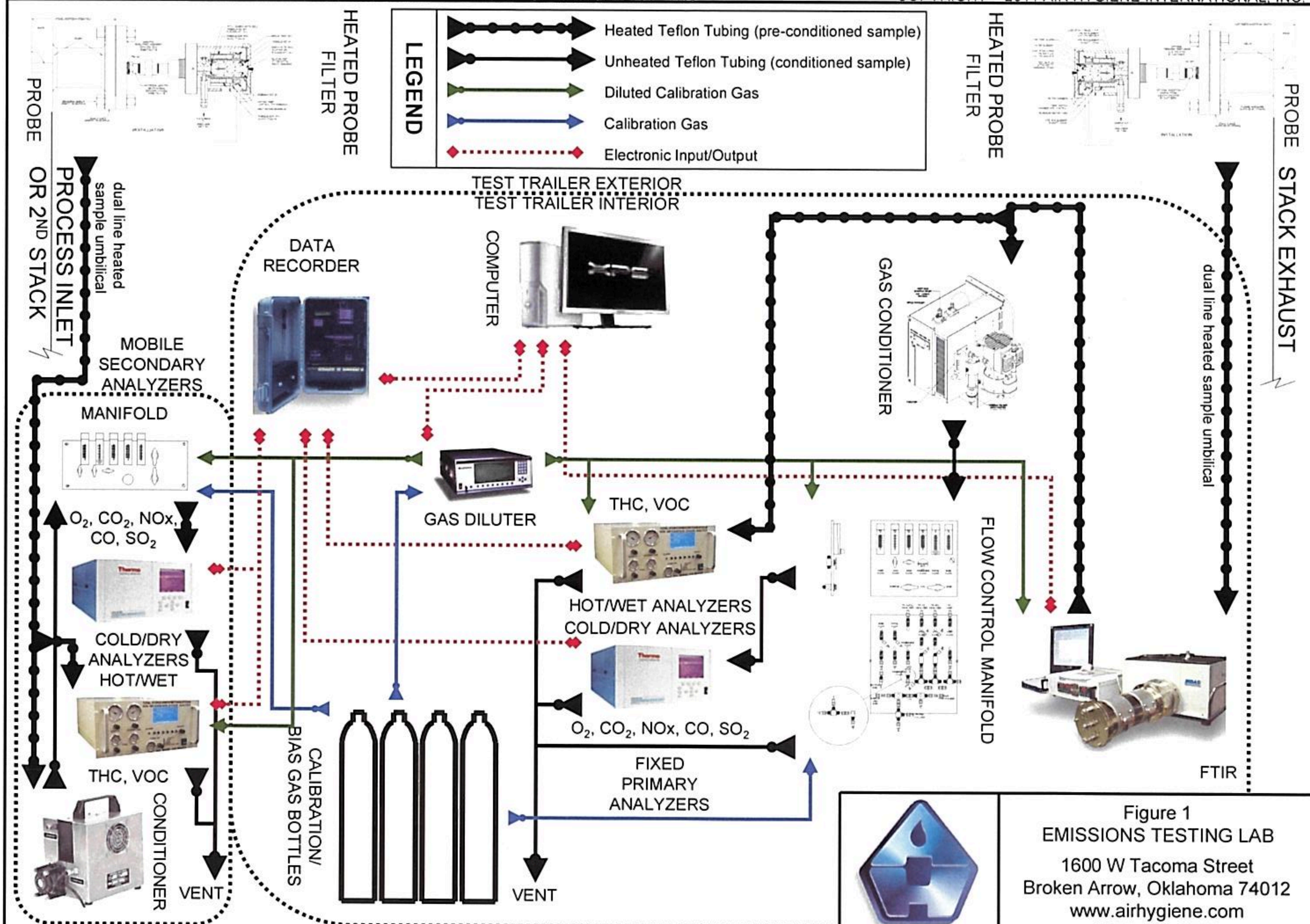

Figure 1
EMISSIONS TESTING LAB

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Broken Arrow, Oklahoma 74012
www.airhygiene.com
(888) 461-8778

Shown fully equipped. Some labs may not contain these features and others may contain additional features specific to certain scopes.

TABLE 1: TESTING MATRIX

Target	EPA Test Method	Locations/Unit Test Load(s)	Test Length
O_2	3A	Combustor / Maximum	3, 60-minute test runs
TOC	25A	Combustor / Maximum	3, 60-minute test runs

TABLE 2: ANALYTICAL INSTRUMENTATION

Parameter	Model and Manufacturer	Common Use Ranges	Sensitivity	Detection Principle
O_2	Servomex or equivalent	0-25%	0.1%	Oxygen - Paramagnetic cell
TOC	TECO 51 or equivalent	User may select up to 3,000 ppm	0.1 ppm	Flame Ionization Detector

TABLE 3: ANALYTICAL INSTRUMENTATION TESTING CONFIGURATION

Parameter	Sample Methodology	Example Range	Calibration Gases (based on example range)
O_2	3A	0-21%	Zero = 0 ppm nitrogen Mid = 8.4 – 12.6% High = 21%
TOC (as methane)	25A	0-1000 ppm	Zero = 0 ppm nitrogen Low = 250 – 350 ppm Mid = 450 – 550 ppm High = 800 – 900 ppm

APPENDIX C

EXAMPLE TEMPLATES AND CALCULATIONS

AIR HYGIENE

ENGINE TEST - FIELD DATA SHEET

Company:		
Location:		
Date:		
Unit Make and Model:		
Unit Number:		
Serial Number:		
Data Recorded By:		
Tested With AHI Unit(s):	Truck(s):	Trailer(s):
LDEQ Warmup/Cal Req:	On (Day/Time):	Cal (Day/Time):

CYLINDER SERIAL NUMBERS		O_2	NOx	CO	THC	CO_2	SO_2
	Low						
	Mid						
	High						

NO_2 CONVERSION	
NO_2 Gas (ppm)	
NO Reading (ppm)	
NOx Reading (ppm)	
Cylinder Num	

Stack Dia. = __________

Measured By: __________

Measured With: __________

RUN INFORMATION	Run #1	Run #2	Run #3	Run #4	Average
Time Start (hh:mm:ss)					
Time Stop (hh:mm:ss)					
Barometric Pressure (in. Hg)					
Ambient Temperature (°F)					
Relative Humidity (%)					
Suction Pressure (psig)					
Discharge Pressure (psig)					
Rated Horsepower (hp)					
Actual Horsepower (hp)					
Fuel Flow (SCF/hr)					
Turbo Speed (npt) or (rpm)					
Engine Speed (npg) or (rpm)					
Air Manifold Temperature (°F)					
Air Manifold Pressure (psig or in. Hg)					
Engine Timing BTDC					

REPORT INFORMATION	INSTRUMENT	SERIAL #
O_2		
NOx		
CO		
THC		
CO_2		
SO_2		

RESPONSE TIME	TIME (hh:mm)	RESP (min)
Gas Inject	/ /	
1st Inst. @ 95%	/ /	/ /
2nd Inst. @ 95%	/ /	/ /
3rd Inst. @ 95%	/ /	/ /

CALIBRATION	O_2		NOx		CO		THC		CO_2	
	Conc.	Actual	Conc.	Actual	Conc.	Actual	Conc.	Actual	Conc.	Actual
Zero Gas										
Low Gas										
Mid Gas										
High Gas										

BIAS	O_2		NOx		CO		THC		CO_2	
	Zero	Mid	Zero	Mid	Zero	Mid	Zero	Mid	Zero	Mid
Initial/Run #1										
Run #1/Run #2										
Run #2/Run #3										
Run #3/Run #4										
Run #4/Final										
Bias Gas Actual Conc.		____		____		____		____		____

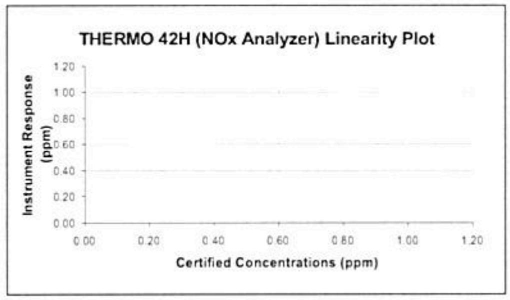
Air Permit # :	
Plant Name or Location:	
Date:	
Project Number:	
Manufacturer & Equipment:	
Model:	
Serial Number:	
Unit Number:	
Test Load:	
Tester(s) / Test Unit(s):	

		RUN																	
	UNITS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Start Time	hh:mm:ss																		
End Time	hh:mm:ss																		
Bar. Pressure	in. Hg																		
Amb. Temp.	°F																		
Rel. Humidity	%																		
Spec. Humidity	lb water / lb air																		
Comb. Inlet Pres.	psig																		
NOx Water Inj.	gpm																		
Total Fuel Flow	SCFH																		
Heat Input	MMBtu/hr																		
Power Output	megawatts																		
Steam Rate	lb/hr																		

Calibration Date:
Client:

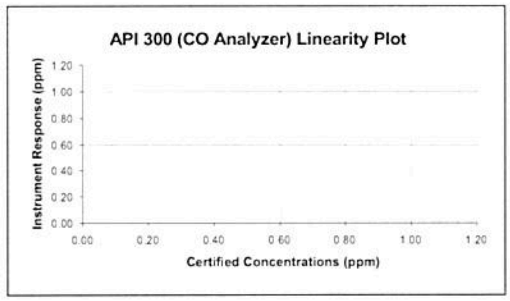
NOx Span (ppm) =

THERMO 42H (NOx Analyzer)				
Certified Concentration (ppm)	Instrument Response (ppm)	Calibration Error (%)	Absolute Conc. (ppm)	Pass or Fail (±2%, ≤0.5ppm)
Linearity =				



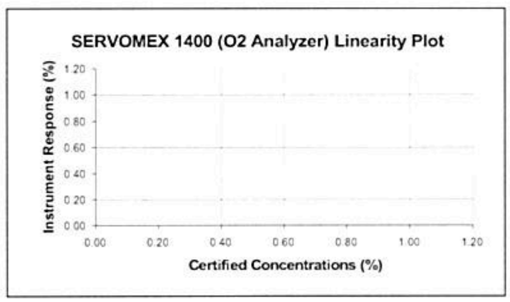
CO Span (ppm) =

API 300 (CO Analyzer)				
Certified Concentration (ppm)	Instrument Response (ppm)	Calibration Error (%)	Absolute Conc. (ppm)	Pass or Fail (±2%, ≤0.5ppm)
Linearity =				



O2 Span (%) =

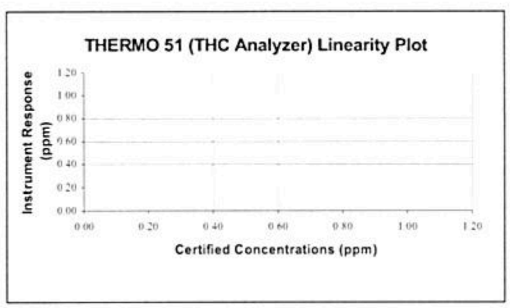
SERVOMEX 1400 (O_2 Analyzer)				
Certified Concentration (ppm)	Instrument Response (ppm)	Calibration Error (%)	Absolute Conc. (ppm)	Pass or Fail (±2%, ≤0.5%)
Linearity =				



THC Range (ppm) =

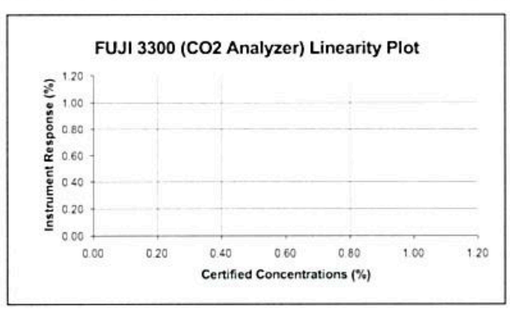
THERMO 51 (THC Analyzer)				
Certified Concentration (ppm)	Instrument Response (ppm)	Calibration Error (%)	Estimated Point (ppm)	Pass or Fail (±2,5%)[1]
Linearity =				

[1]-zero/high based on 2% of span,low/mid based on 5% of concentration



CO2 Span (%) =

FUJI 3300 (CO_2 Analyzer)				
Certified Concentration (ppm)	Instrument Response (ppm)	Calibration Error (%)	Absolute Conc. (ppm)	Pass or Fail (±2%, ≤0.5%)
Linearity =				



Fuel Data

Fuel F_c factor		SCF/MMBtu
Fuel Heating Value (HHV)		Btu/SCF

Weather Data

Barometric Pressure		in. Hg
Relative Humidity		%
Ambient Temperature		°F
Specific Humidity		lb H_2O / lb air

Unit Data

Unit Load		megawatts
Heat Input		lb/MMBtu
Steam Rate		Steam lb/hr
Combustor Inlet Pres.		psig
NOx Control Water Injection		gpm
Est. Stack Moisture		%
Stack Exhaust Flow (M2)		SCFH
Stack Exhaust Flow (M19)		SCFH

Run - 1

Date/Time (mm/dd/yy hh:mm:ss)	Elapsed Time (seconds)	O_2 (%)	NOx (ppmvd)	CO (ppmvd)

RAW AVERAGE

		O_2	NOx	CO
	Serial Number:			
		(%)	(ppmvd)	(ppmvd)
Bias	Initial Zero			
	Final Zero			
	Avg. Zero			
	Initial UpScale			
	Final UpScale			
	Avg. UpScale			

Upscale Cal Gas

EMISSIONS DATA	O_2	NOx	CO
Corrected Raw Average (ppm/% dry basis)			
Corrected Raw Average (ppm/% wet basis)			
Concentration (ppm@ %O_2)			
Concentration (ppm@ %O_2 &ISO)			
Emission Rate (lb/hr)			
Emission Rate (tons/day) at 24 hr/day			
Emission Rate (tons/year) at 8760 hr/yr			
Emission Rate (lb/MMBtu)			
Emission Rate (g/hp*hr)			

DRIFT AND BIAS CHECK			
Run - 1	O2	NOx	CO
Raw Average			
Corrected Average			
Initial Zero			
Final Zero			
Avg. Zero			
Initial UpScale			
Final UpScale			
Avg. UpScale			
Sys Resp (Zero)			
Sys Resp (Upscale)			
Upscale Cal Gas			
Initial Zero Bias			
Final Zero Bias			
Zero Drift			
Initial Upscale Bias			
Final Upscale Bias			
Upscale Drift			
Alternative Specification Abs Diff — Initial Zero			
Final Zero			
Initial Upscale			
Final Upscale			
Calibration Span			
3% of Range (drift)			
5% of Range (bias)			

DRIFT AND BIAS CHECK			
Run - 2	O2	NOx	CO
Raw Average			
Corrected Average			
Initial Zero			
Final Zero			
Avg. Zero			
Initial UpScale			
Final UpScale			
Avg. UpScale			
Sys Resp (Zero)			
Sys Resp (Upscale)			
Upscale Cal Gas			
Initial Zero Bias			
Final Zero Bias			
Zero Drift			
Initial Upscale Bias			
Final Upscale Bias			
Upscale Drift			
Alternative Specification Abs Diff — Initial Zero			
Final Zero			
Initial Upscale			
Final Upscale			
Calibration Span			
3% of Range (drift)			
5% of Range (bias)			

EMISSION CALCULATIONS SUMMARY TABLES

Company:
Engine Tested:
Engine Serial #:

Date:
Location:

Stack Gas Flow Rate: Method 19

Test #	Brake Horsepower	O_2 Conc. (%)	Fuel Heating Value (Btu/SCF)	F Factor-Dry Oxy. (DSCFex/MMBtu)	Fuel Flow (SCF/hr)	Stack Flow (SCF/hr)
1						
2						
3						
Average						

NOx Mass Emission Rate

Test #	Brake Horsepower	NOx Conc. (ppmvd)	MW	E (g/hp*hr)	E (lb/hr)	E (ton/yr)	E (lb/MMBtu)
1			46.01				
2			46.01				
3			46.01				
Average			**46.01**				

CO Mass Emission Rate

Test #	Brake Horsepower	CO Conc. (ppmvd)	MW	E (g/hp*hr)	E (lb/hr)	E (ton/yr)	E (lb/MMBtu)
1			28.00				
2			28.00				
3			28.00				
Average			**28.00**				

Fuel Flow (Btu/hp•hr) is based upon the worst case assumption of 8,500 Btu/hp•hr fuel usage when site data for fuel flow is not available.

TABLE 2.1: ENGINE EMISSIONS REPORT

Test Period:				Air Permit Number:	
Location:				Unit Number:	
Date:				Suction Pressure (psi):	
Project Number:				Discharge Pressure (psi):	
Engine Manufacturer:				Stack Exhaust Temperature (°F):	
Engine Model:				Rated Horsepower (hp):	
Engine Serial Number:				Brake Horsepower (bhp):	
Analyzer Manufacturers:	TECO(NOx), API(CO), TECO(THC)			Engine Fuel Flow (SCFH):	
Analyzer Model Numbers:	42H, 300, 51			Specific Gravity:	
Date Analyzers Calibrated:				Fuel Heating Value [HHV] (Btu/SCF):	
Emission Test Results:	Appendix A			BSFC (Btu/hp*hr):	
Analyzer Data Plots:	Appendix B			Annual Hours Allowed to Operate:	8,760
Cal Gas Spec. Sheets:	Appendix C			Engine Speed (rpm):	
Quality Control Data Sheets:	Appendix D			Air Manifold Temp (°F):	
Chromatograph Report:	Appendix E			Air Manifold Pressure (psi):	
Ambient Temperature (°F):				Turbo Speed (rpm):	
Barometric Pressure (in. Hg):				Engine Ignition Timing (°BTDC):	
Relative Humidity (%):				Load Step:	
				Torque (%):	
				Tested By: Air Hygiene International, Inc.	

Emission Test Results			
Pollutant (units)	Stack Test Results	Permit Limits	Passing
NOx (avg. ppmvd)			
CO (avg. ppmvd)			
VOC (avg. ppmvd)			
NOx @15%O_2 O_2 (avg. ppmvd)			
CO @15%O_2 O_2 (avg. ppmvd)			
VOC @15%O_2 O_2 (avg. ppmvd)			
NOx (avg. lb/hr)			
CO (avg. lb/hr)			
VOC (avg. lb/hr)			
NOx (avg. g/hp*hr)			
CO (avg. g/hp*hr)			
VOC (avg. g/hp*hr)			

All testing conducted according to United States Environmental Protection Agency (EPA), Methods: 7e, 10 and 25a.

EXAMPLE CALCULATIONS (FFACTOR)

RM 19, (07-19-06),
2.0 Summary of Method,
2.1 Emission Rates. Oxygen (O_2) or carbon dioxide (CO_2) concentrations and appropriate F factors (ratios of combustion gas volumes to heat inputs) are used to calculate pollutant emission rates from pollutant co

RM 19, (07-19-06),
12.2 Emission Rates of PM, SO2, and NOx. Select from the following sections the applicable procedure to compute the PM, SO2, or NOx emission rate (E) in lb/MMBtu. The pollutant concentration must be in lb/scf and the F factor must be in scf/MMBtu. If the pollutant concentration (C) is not in the appropriate units, use Table 19–1 in Section 17.0 to make the proper conversion. An F factor is the ratio of the gas volume of the products of combustion to the heat content of the fuel. The dry F factor (F_d) includes all components of combustion less water, the wet F factor (F_w) includes all components of combustion, and the carbon F factor (F_c) includes only carbon dioxide.

Mark's Std Hdbk, 10th ed.,pg 4-26
High Heat Value Dry (HHV_{dry}), calc for Methane (single component for the fuel gas)

$$HHV_{dry}\,(Btu/SCF) = \left[\left(\frac{M_{\%}}{100}\right) \times GCM\right]$$

$$HHV_{dry} = \frac{\%}{100.00} \times \frac{Btu}{SCF} = \frac{Btu}{SCF}$$

Mark's Std Hdbk, 10th ed., pg 4-26
Low Heat Value Dry (LHV_{dry}), calc for Methane (single component for the fuel gas)

$$LHV_{dry}\,(Btu/SCF) = \left[\left(\frac{M_{\%}}{100}\right) \times NCM\right]$$

$$LHV_{dry} = \frac{\%}{100.00} \times \frac{Btu}{SCF} = \frac{Btu}{SCF}$$

Civil Eng. Ref. Man.,7th Ed.,pg 14-9/GPA Ref. Bulletin 181-86, App. C
High Heat Value Wet (HHV_{wet}), calc for entire sample (all components of the fuel gas)

$$HHV_{wet}\,(Btu/SCF) = \frac{HHV_{dry}}{W/D.\,factor}$$

$$HHV_{wet} = \frac{Btu/SCF}{} = Btu/SCF$$

Civil Eng. Ref. Man.,7th Ed.,pg 14-9/GPA Ref. Bulletin 181-86, App. C
Low Heat Value Wet (LHV_{wet}), calc for entire sample (all components of the fuel gas)

$$LHV_{wet}\,(Btu/SCF) = \frac{LHV_{dry}}{W/D.\,factor}$$

$$LHV_{wet} = \frac{Btu/SCF}{} = Btu/SCF$$

Lbs Component per Lb-Mol of Gas (CM), calc for Methane (single component for the fuel gas)

$$CM\,(lb/lb-mol) = \left[\left(\frac{M_{\%}}{100}\right) \times MW\right]$$

$$CM = \frac{\%}{100.00} \times \frac{lb}{lb\text{-}mol} = \underline{}\ lb/lb\text{-}mol$$

ASTM D 3588
Fuel Molecular Weight (MW_{Fuel})

$$MW_{Fuel}\,(lb/lb\cdot mol) = \left[\sum(CM)\right]$$

MW_{Fuel} = lb/lb-mol
\+ lb/lb-mol
\+ etc. = lb/lb-mol

Btu per Lb of Gas Gross (**GCV**)

$$GCV\,(Btu/lb) = \left[\frac{HHV_{dry} \times G}{MW_{Fuel}}\right]$$

$$GCV = \frac{Btu/SCF \times ft^3/lbmol}{lb/lb\text{-}mol} = Btu/lb$$

ASTM D 3588 (SG)
Specific Gravity

$$SG = \left[\frac{MW_{Fuel}}{MW_{AIR}}\right]$$

$$SG = \frac{lb/lb\text{-}mol}{28.96\ lb/lb\text{-}mol} =$$

Btu per Lb of Gas Net (**NCV**)

$$NCV\,(Btu/lb) = \left[\frac{LHV_{dry} \times G}{MW_{Fuel}}\right]$$

$$NCV = \frac{Btu/SCF \times ft^3/lbmol}{lb/lb\text{-}mol} = Btu/lb$$

Weight Percent of Component ($C_{\%}$), methane

$$C_{\%}(\%) = \left[\left(\frac{CM}{MW_{Fuel}}\right) \times 100\right]$$

$$C_{\%} = \frac{lb/lb\text{-}mol}{lb/lb\text{-}mol} \times 100 = \%$$

RM 19, (07-19-06), **Weight Percent of Volatile Organic Compounds** ($VOC_{\%}$)

$$VOC_{\%}(\%) = \left[\sum_{C_3H_8}^{C_nH_n} M_{\%}\right]$$

$$VOC_{\%} = \% + \% + \% + \text{etc.} = \%$$

RM 19, (07-19-06), 12.3.2 Determined **F Factors**. If the fuel burned is not listed in Table 19–2 or if the owner or operator chooses to determine an F factor rather than use the values in Table 19–2, use the procedure below: 12.3.2.1 Equations. Use the eq

RM 19, (07-19-6),
12.1 Nomenclature

$$F_d = \frac{K(K_{hd}\%H + K_c\%C + K_s\%S + K_n\%N - K_o\%O)}{GCV} \qquad \text{Eq. 19-13}$$

K (scf/lb)/%

H	3.64
C	1.53
S	0.57
N_2	0.14
O_2	0.46

$$F_d = \frac{10^6 Btu}{MMBtu} \times \left[\frac{3.64\ SCF}{lb\cdot\%} \times \% + \frac{1.53\ SCF}{lb\cdot\%} \times \% + \frac{0.57\ SCF}{lb\cdot\%} \times \% + \frac{0.14\ SCF}{lb\cdot\%} \times \% - \frac{0.46\ SCF}{lb\cdot\%} \times \%\right] \times \frac{lb}{Btu} = \frac{SCF}{MMBtu}$$

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (INFORMATION)

Specific Humidity (RH_{sp})

Note: RHsp (gr/lb) calculated using temperature, relative humidity, and barometric pressure with psychrometric chart, psychrometric calculator, or built in psychrometric algorithm.

$$RH_{sp}(lb/lb) = \left[\left(\frac{gr}{lb}\right) \times \frac{lb}{7000\ gr}\right]$$

$$RH_{sp} = \frac{\quad gr}{lb} \times \frac{1\ lb}{7000\ gr} = \frac{lb\ H_2O}{lb\ Air}$$

Fuel Flow Conversion (Q_f)

Note: Qf(lb/min) is a value uptained from the source operator.

$$Q_f = \left[Q_f \times G \times \left(\frac{1}{MW_{Fuel}}\right)\right]$$

$$Q_f = \frac{\quad lb}{min} \times \frac{60\ min}{hr} \times \frac{\quad ft^3}{lb\text{-}mol} \times \frac{lb\text{-}mol}{\quad lb} = \quad SCFH$$

Combustor Inlet Pressure / Compressor Discharge Pressure (CIP / CDP)
(corrected from gauge to atmospheric pres. and conv. to mm Hg.)

Note: CIP / CDP (psig) is a value obtained from the source operator.

$$CIP / CDP = \left[(psig + P) \times \frac{51.71493\ mmHg}{1\ psi}\right]$$

$$CIP / CDP = (\quad psig + \quad) \times \frac{51.71493\ mmHg}{1\ psia} = \quad mmHg\ (abs)$$

Heat Rate (MMBtu/hr)

$$HR = \frac{HHV_{DRY} \times Q_f}{1{,}000{,}000}$$

$$\text{Heat Rate} = \frac{\quad Btu}{SCF} \times \frac{\quad SCF}{hr} \times \frac{MMBtu}{10^6\ Btu} = \frac{\quad MMBtu}{hr}$$

Estimated Stack Gas Moisture Content (B_{ws})

$$B_{ws}(\%) = \frac{2 \times Q_f}{Q_s} \times 100$$

$$B_{ws} = 2 \times \frac{\quad SCF}{hr} \times \frac{\quad hr}{SCF} \times 100 = \quad \%$$

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (CALIBRATION)

Analyzer Calibration Error

RM 7E, (08-15-06), 12.2 Analyzer Calibration Error. For non-dilution systems, use Equation 7E-1 to calculate the analyzer calibration error for the low-, mid-, and high-level calibration gases. (calc for analyzer mid gas, if applicable)

$$ACE = \left(\frac{C_{Dir} - C_V}{CS}\right) \times 100 \qquad \text{Eq. 7E-1}$$

$$ACE = \frac{\quad ppm - \quad ppm}{\quad ppm} \times 100 = \quad \%$$

Calibration Error and Estimated Point, RM 25A, THC Analyzer

RM 25A, (07-19-06), 8.4 Calibration Error Test. Immediately prior to the test series (within 2 hours of the start of the test), introduce zero gas and high-level calibration gas at the calibration valve assembly. Adjust the analyzer output to the appropriate levels, if necessary. Calculate the predicted response for the low-level and mid-level gases based on a linear response line between the zero and high-level response. Then introduce low-level and mid-level calibration gases successively to the measurement system. ... These differences must be less than 5 percent of the respective calibration gas value. (calc for THC analyzer mid gas, if applicable)

$$E_P = \frac{C_{Dir(H)} - C_{Dir(Z)}}{C_{V(H)} - C_{V(Z)}} \times C_{Dir(M)} + C_{Dir(Z)}$$

Eq. of a line
y=mx+b

$$E_p = \frac{\quad ppm - \quad ppm}{\quad ppm - \quad ppm} \times \quad ppm + \quad = \quad ppm$$

$$ACE = \left(\frac{C_{Dir} - C_V}{CS}\right) \times 100 \qquad \text{Eq. 7E-1}$$

$$ACE_{THC} = \frac{\quad ppm - \quad ppm}{\quad ppm} \times 100 = \quad \%$$

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (BIAS, DRIFT, AND CORRECTED RAW AVERAGE)

System Bias

RM 7E, (08-15-06), 12.3 System Bias. For non-dilution systems, use Equation 7E-2 to calculate the system bias separately for the low-level and upscale calibration gases. (calc for analyzer upscale gas, Run 1 initial bias, if applicable)

$$SB = \left(\frac{C_S - C_{Dir}}{CS} \right) \times 100$$ Eq. 7E-2

$$SB = \frac{\text{ ppm - } \quad \text{ ppm}}{\text{ppm}} \times 100 = \quad \%$$

Drift Assessment

RM 7E, (08-15-06), 12.5 Drift Assessment. Use Equation 7E-4 to separately calculate the low-level and upscale drift over each test run. (calc for analyzer upscale drift, Run 1, if applicable)

$$D = \left| SB_{final} - SB_i \right|$$ Eq. 7E-4

$$D = | \quad \% - \quad \% \quad | = \quad \%$$

Alternative Drift and Bias

RM 7E, (08-15-06), 13.2 / 13.3 System Bias and Drift. Alternatively, the results are acceptable if |Cs – Cdir| is≤ 0.5 ppmv or if |Cs – Cv| is ≤ 0.5 ppmv (as applicable). (calc for analyzer initial upscale, Run 1, if applicable)

$$SB / D_{Alt} = \left| C_S - C_{Dir} \right|$$ Eq. Section 13.2 and 13.3

$$SB / D_{Alt} = | \quad \text{ppm} - \quad \text{ppm} \quad | = \quad \text{ppm}$$

Bias Adjusted Average

RM 7E, (08-15-06), 12.6 Effluent Gas Concentration. For each test run, calculate Cavg, the arithmetic average of all valid concentration values (e.g., 1-minute averages). Then adjust the value of Cavg for bias, using Equation 7E-5. (calc for analyzer, Run 1, if applicable)

$$C_{Gas} = \left(C_{Avg} - C_O \right) \times \left(\frac{C_{MA}}{C_M - C_O} \right)$$ Eq. 7E-5

$$C_{Gas} = \left(\quad \text{ppm} - \quad \text{ppm} \right) \times \left(\frac{\text{ppm}}{\text{ppm} - \quad \text{ppm}} \right) = \quad \text{ppm}$$

EXAMPLE CALCULATIONS (BSFC)

Using LHV with Q_f (Btu/hp*hr)

$$BSFC\ (Btu / hp \cdot hr) = Q_f$$

$$BSFC = \frac{\text{Btu}}{\text{hp*hr}} = \frac{\text{Btu}}{\text{hp*hr}}$$

Using HHV with Q_f (SCFH)

$$BSFC\ (Btu / hp \cdot hr) = \frac{HHV \times Q_f}{bhp}$$

$$BSFC = \frac{\text{Btu}}{\text{SCF}} \times \frac{\text{SCF}}{\text{hr}} \times \frac{1}{\text{hp}} = \frac{\text{Btu}}{\text{hp*hr}}$$

Using LHV with Q_f (SCFH)

$$BSFC\ (Btu / hp \cdot hr) = \frac{LHV \times Q_f}{bhp}$$

$$BSFC = \frac{\text{Btu}}{\text{SCF}} \times \frac{\text{SCF}}{\text{hr}} \times \frac{1}{\text{hp}} = \frac{\text{Btu}}{\text{hp*hr}}$$

Using HHV with Q_f (Btu/hp*hr)

$$BSFC\ (Btu / hp \cdot hr) = \frac{Q_f \times HHV}{LHV}$$

$$BSFC = \frac{\text{N/A Btu}}{\text{hp*hr}} \times \frac{\text{Btu}}{\text{SCF}} \times \frac{\text{scf}}{\text{Btu}} = \frac{\text{Btu}}{\text{hp*hr}}$$

EXAMPLE CALCULATIONS (Emissions based on Table 29 values)

Emission Rate (lb/hr)
Q_f (Btu/hp*hr))

$$E(lb / hr) = \frac{E_{g/hp \cdot hr} \times bhp}{453.6}$$

$$E\ (lb/hr) = \frac{\text{g}}{\text{hp*hr}} \times \frac{\text{lb}}{\text{453.6 g}} \times \quad \text{hp} = \frac{\text{lb}}{\text{hr}}$$

Emission Rate (g/hp-hr)
Q_f (Btu/hp*hr))

$$E(g / hp \cdot hr) = CRA \times Q_f \times FFactor \times MW \times \frac{1}{10^6} \times \frac{1}{10^6} \times \frac{453.6}{G} \times \frac{20.9\%}{20.9\% - CRA_{O_2}}$$

$$E\ (g/hp\text{-}hr) = \text{ppm} \times \frac{\text{Btu}}{\text{hp*hr}} \times \frac{\text{SCF}}{\text{MMBtu}} \times \frac{\text{lb}}{\text{lb-mol}} \times \frac{\text{1 parts}}{10^6\ \text{ppm}} \times \frac{\text{1 MMBtu}}{10^6\ \text{Btu}}$$

$$\times \frac{\text{453.6 g}}{\text{lb}} \times \frac{\text{lb-mol}}{\text{SCF}} \times \frac{20.9\%}{20.9\% - \quad \%} = \frac{\text{g}}{\text{hp*hr}}$$

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (RUNS)

Stack Exhaust Flow (Q_S) - RM19

$$Q_S = \left(\frac{FFactor \times Q_f \times HHV}{1{,}000{,}000}\right) \times \left(\frac{20.9\%}{20.9\% - C_{Gas(O2)}}\right)$$

Note: Equation presented in EPA Emission Measurement Center (EMC), Frequently Asked Questions (FAQ) for Method 19

$Q_S = \frac{\text{SCF}}{\text{MMBtu}} \times \frac{\text{SCF}}{\text{hr}} \times \frac{\text{Btu}}{\text{SCF}} \times \frac{\text{MMBtu}}{10^6\ \text{Btu}} \times \left[\frac{20.90\%}{20.9\% - \quad \%}\right] =$ SCFH

NO_2 Conversion Efficiency Correction

RM 7E, (02-27-14), 12.8 NO_2 - NO Conversion Efficiency Correction. If desired, calculate the total NOx concentration with a correction for converter efficiency using Equations 7E-8. (calc for non-bias corrected (raw) NOx gas, Run 1, if applicable)

$$NOx_{Corr} = NO + \frac{NOx - NO}{Eff_{NO2}} \times 100$$ Eq. 7E-8

$NOx_{Corr} =$ ppm $+ \frac{\text{ppm} - \quad \text{ppm}}{\%} \times 100 =$ ppm

Moisture Correction

RM 7E, (02-27-14), 12.10 Moisture Correction. Use Equation 7E-10 if your measurements need to be corrected to a dry basis. (calc for analyzer, Run 1, if applicable) Note: Calculations may not match as Run 1 results are typically also bias adjusted

$$C_D = \frac{C_W}{1 - B_{WS}}$$ Eq. 7E-10

$C_D = \frac{\text{ppmvw}}{1 -} =$ ppmvd or inversely,

$$C_W = C_D \times (1 - B_{WS})$$

$C_W =$ ppmvd $\times \left(1 - \quad\right) =$ ppmvw

Diluent-Corrected Pollutant Concentration, O_2 Based

RM 20, (11-26-02), 7.3.1 Correction of Pollutant Concentration Using O_2 Concentration. Calculate the O_2 corrected pollutant concentration, as follows: (calc for gas, Run 1, if applicable) [now contained in applicable Subpart]

$$C_{adj} = C_{Gas(Target)} \times \left(\frac{20.9\% - AdjFactor}{20.9\% - C_{Gas(O2)}}\right)$$ Eq. 20-4

$C_{adj} =$ ppm $\times \left(\frac{20.9\% - \quad \%}{20.9\% - \quad \%}\right) =$

Diluent-Corrected Pollutant Concentration, CO_2 Based

Calculate the CO_2 corrected pollutant concentration, as follows: (calc for gas, Run 1, if applicable)

$$C_{adj} = C_{Gas(Target)} \times \left(\frac{AdjFactor}{C_{Gas(CO2)}}\right)$$

$C_{adj} =$ ppm $\times \left(\frac{\%}{\%}\right) =$

Diluent-Corrected Pollutant Concentration, O_2 Based with CO_2 Measurements

RM 20, (11-26-02), 7.3.2 Correction of Pollutant Concentration to Percent O_2 Using CO_2 Concentration. Calculate the O_2 corrected pollutant concentration, as follows: (calc for gas, Run 1, if applicable) [now contained in applicable Subpart]

$$C_{adj} = C_{Gas(Target)} \times \frac{X_{CO2}}{C_{Gas(CO2)}}$$ Eq. 20-5

$C_{adj} =$ ppm $\times \frac{\%}{\%} =$

7.2 CO_2 Correction Factor. If pollutant concentrations are to be corrected to percent O_2 and CO_2 concentration is measured in lieu of O_2 concentration measurement, a CO_2 correction factor is needed. Calculate the CO_2 correction factor as follows: 7.2.1 Calculate the fuel specific F_o, as follows: 7.2.2. Calculate the CO_2 correction factor for correcting measurement data to percent oxygen, as follows:

Eq. 20-2 $$F_o = \frac{0.209\, F_d}{F_c}$$

$F_0 = \frac{0.209 \times \quad \text{SCF/MMBtu}}{\text{SCF/MMBtu}} =$

Eq. 20-3 $$X_{CO2} = \frac{20.9\% - AdjFactor}{F_0}$$

$X_{CO2} = \frac{20.9\% - \quad \%}{} =$ %

Diluent-Corrected Pollutant Concentration Corrected to ISO Conditions

40CFR60.335(b)(1), Conversion for conc. at ISO Conditions (68°F, 1 atm). Calculate, as follows: (calc for @% with Run 1 data, if applicable)

$$C_{ISO} = C_{Adj} \times \sqrt{\frac{P_r}{P_o}} \times e^{(19 \times (H_o - 0.00633))} \times \left(\frac{288}{T_a}\right)^{1.53}$$

$C_{ISO} = \quad \times \left(\sqrt{\dfrac{\dfrac{\text{psig} + 14.69232\ \text{psi}}{0.01933677\ \text{psi/mm Hg.}}}{\dfrac{\text{psig} + \quad \text{psi}}{0.01933677\ \text{psi/mm Hg.}}}}\right) \times 2.718^{(19 \times (\quad \text{lb/lb} - 0.00633))} \times \left(\frac{288\ \text{K}}{\text{K}}\right)^{1.53} =$ ppm@% and ISO

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (RUNS)

Emissions Rate (lb/hr)

Calculation for pound per hour emission rate. Calculate, as follows: (calc for gas Run 1, if applicable)

$$E_{lb/hr} = \frac{C_{Gas}}{10^6} \times \frac{Q_S \times MW}{G}$$

$$E_{lb/hr} = \frac{\text{ppm}}{10^6 \text{ ppm/part}} \times \frac{\text{SCFH x} \quad \text{lb/lb-mol}}{\text{SCF/lb-mol}} = \frac{\text{lb}}{\text{hr}}$$

Emissions Rate (ton/year)

Calculation for tons per year emission rate based on 8760 hours per year. Calculate, as follows: (calc for gas Run 1, if applicable)

$$E_{ton/yr} = \frac{E_{lb/hr} \times hr_{year}}{2000}$$

$$E_{ton/yr} = \frac{\text{lb}}{\text{hr}} \times \frac{\text{hr}}{\text{year}} \times \frac{\text{ton}}{\text{2000 lb}} = \frac{\text{ton}}{\text{year}}$$

Emissions Rate (lb/MMBtu)

RM 19, (07-19-06), 12.2 Emission Rates of PM, SO2, and NOx. Select from the following sections the applicable procedure to compute the PM, SO2, or NOx emission rate (E) in ng/J (lb/million Btu). (calc for gas Run 1, if applicable)

Oxygen Based

12.2.1 Oxygen-Based F Factor, Dry Basis. When measurements are on a dry basis for both O_2 (%O_2d) and pollutant (Cd) concentrations, use the following equation:

$$E_{lb/MMBtu} = \frac{C_{Gas} \times F_d Factor \times Conv_C \times 20.9\%}{20.9\% - C_{Gas(O2)}} \qquad \text{Eq. 19-1}$$

$$E_{lb/MMBtu} = \frac{\text{ppm x} \quad \text{SCF/MMBtu x} \quad \text{lb/ppm*ft}^3 \text{ x } 20.9\%}{20.9\% - \quad \%} = \frac{\text{lb}}{\text{MMBtu}}$$

Carbon Dioxide Based

12.2.4 Carbon Dioxide-Based F Factor, Dry Basis. When measurements are on a dry basis for both CO_2 (%CO_2d) and pollutant (Cd) concentrations, use the following equation:

$$E_{lb/MMBtu} = \frac{C_{Gas} \times F_d Factor \times Conv_C \times 100\%}{C_{Gas(CO2)}} \qquad \text{Eq. 19-6}$$

$$E_{lb/MMBtu} = \frac{\text{ppm x} \quad \text{SCF/MMBtu x} \quad \text{lb/ppm*ft}^3 \text{ x } 100\%}{\%} = \frac{\text{lb}}{\text{MMBtu}}$$

Conversion Constant

Convc for

$$Conv_c (lb / ppm \cdot ft^3) = \frac{\frac{MW}{G}}{10^6}$$

$$Conv_c = \frac{\frac{\text{lb}}{\text{lb•mole}} \times \frac{\text{lb•mole}}{\text{SCF}}}{10^6} = \frac{\text{lb}}{\text{ppm-ft}^3}$$

Sulfur Dioxide Rate (lb/MMBtu), 40CFR60, App. A, RM 19, Eq. 19-25 (11/20/03)

$$SO_2 (lb / MMBtu) = 0.97 \times K \times \frac{S(wt\%)}{GCV}$$

$$SO_2 = 0.97 \times \frac{2\text{x}10^4 \text{ Btu}}{\text{wt\%•MMBtu}} \times \frac{\text{wt\%}}{\text{Btu/lb}} = \frac{\text{lb}}{\text{MMBtu}}$$

Emissions Rate (g/hp-hr)

Calculation for grams per horsepower-hour. Calculate, as follows: (calc for gas Run 1, if applicable)

$$E_{g/hp\cdot hr} = \frac{E_{lb/hr} \times 453.6}{mw \times 1341.022} \; or \; \frac{E_{lb/hr} \times 453.6}{hp}$$

$$E_{g/hp\text{-}hr} = \frac{\text{lb}}{\text{hr}} \times \frac{453.6 \text{ g}}{\text{lb}} \times \frac{1}{\text{mw}} \times \frac{\text{mw}}{1341.022 \text{ hp}} = \frac{\text{g}}{\text{hp*hr}}$$

$$E_{g/hp\text{-}hr} = \frac{\text{lb}}{\text{hr}} \times \frac{453.6 \text{ g}}{\text{lb}} \times \frac{1}{\text{hp}} = \frac{\text{g}}{\text{hp*hr}}$$

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (FTIR SPIKE)

Concentration to dilute by 90% (ppmvw)

$$AVG_d = \frac{AVG_r}{2}$$

$$AVG_d = \frac{\text{ppmvw}}{2} = \quad \text{ppmvw}$$

Ideal matrix spike yield (ppmvw)

$$Y_{ideal} = AVG_d \times \left(\frac{Q_m}{Q_{sys}}\right) + AVG_r \times \left(1 - \frac{Q_m}{Q_{sys}}\right)$$

$$Y_{ideal} = \quad \text{ppmvw x} \left(\frac{\text{lpm}}{\text{lpm}}\right) + \quad \text{ppmvw x} \left(1 - \frac{\text{lpm}}{\text{lpm}}\right) = \quad \text{ppmvw}$$

Minimum matrix spike yield (ppmvw)

$$Y_{min} = Y_{ideal} \times 0.7$$

$$Y_{ideal} = \quad \text{ppmvw x } 0.7 = \quad \text{ppmvw}$$

Maximum matrix spike yield (ppmvw)

$$Y_{max} = Y_{ideal} \times 1.3$$

$$Y_{ideal} = \quad \text{ppmvw x } 1.3 = \quad \text{ppmvw}$$

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

RM 7E, (08-15-06), 12.1 Nomenclature. The terms used in the equations are defined as follows:

ACE = Analyzer calibration error, percent of calibration span.
B_{WS} = Moisture content of sample gas as measured by Method 4 or other approved method, percent/100.
C_{Avg} = Average unadjusted gas concentration indicated by data recorder for the test run.
C_D = Pollutant concentration adjusted to dry conditions.
C_{Dir} = Measured concentration of a calibration gas (low, mid, or high) when introduced in direct calibration mode.
C_{Gas} = Average effluent gas concentration adjusted for bias.
C_M = Average of initial and final system calibration bias (or 2-point system calibration error) check responses for the upscale calibration gas.
C_{MA} = Actual concentration of the upscale calibration gas, ppmv.
C_O = Average of the initial and final system calibration bias (or 2-point system calibration error) check responses from the low-level (or zero) calibration gas.
C_S = Measured concentration of a calibration gas (low, mid, or high) when introduced in system calibration mode.
C_{SS} = Concentration of NOx measured in the spiked sample.
C_{Spike} = Concentration of NOx in the undiluted spike gas.
C_{Calc} = Calculated concentration of NOx in the spike gas diluted in the sample.
C_V = Manufacturer certified concentration of a calibration gas (low, mid, or high).
C_W = Pollutant concentration measured under moist sample conditions, wet basis.
CS = Calibration span.
D = Drift assessment, percent of calibration span.
E_p = The predicted response for the low-level and mid-level gases based on a linear response line between the zero and high-level response.
Eff_{NO2} = NO_2 to NO converter efficiency, percent.
H = High calibration gas, designator.
L = Low calibration gas, designator.
M = Mid calibration gas, designator.
NOFinal = The average NO concentration observed with the analyzer in the NO mode during the converter efficiency test in Section 16.2.2.
NOxCorr = The NOx concentration corrected for the converter efficiency.
NOxFinal = The final NOx concentration observed during the converter efficiency test in Section 16.2.2.
NOxPeak = The highest NOx concentration observed during the converter efficiency test in Section 16.2.2.
Q_{Spike} = Flow rate of spike gas introduced in system calibration mode, L/min.
Q_{Total} = Total sample flow rate during the spike test, L/min.
R = Spike recovery, percent.
SB = System bias, percent of calibration span.
SB_i = Pre-run system bias, percent of calibration span.
SB_f = Post-run system bias, percent of calibration span.
SB / D_{Alt} = Alternative absolute difference criteria to pass bias and/or drift checks.
SCE = System calibration error, percent of calibration span.
SCE_i = Pre-run system calibration error, percent of calibration span.
SCE_{final} = Post-run system calibration error, percent of calibration span.
Z = Zero calibration gas, designator.

40CFR60.355(b)(1), (09-20-06), Nomenclature. The terms used in the equations are defined as follows:

P_r = reference combustor inlet absolute pressure at 101.3 kilopascals ambient pressure, mm Hg
P_o = observed combustor inlet absolute pressure at test, mm Hg
H_o = observed humidity of ambient air, g H_2O/g air
e = transcendental constant, 2.718
T_a = ambient temperature, K

Small Engine and FTIR Nomenclature. The terms used in the equations are defined as follows:

bhp = brake horsepower
hp = horsepower
Q_{sys} = system flow (lpm)
Q_m = matrix spike flow (lpm)

RM 19, (07-29-06), 12.1 Nomenclature. The terms used in the equations are defined as follows:

AdjFactor = percent oxygen or carbon dioxide adjustment applied to a target polltant

B_{wa} = Moisture fraction of ambient air, percent.

Btu = British thermal unit

$\%_C$ = Concentration of carbon from an ultimate analysis of fuel, weight percent.

$\%_{CO2d}$, $\%_{CO2w}$ = Concentration of carbon dioxide on a dry and wet basis, respectively, percent.

CIP / CDP = Combustor inlet pressure / compressor discharge pressure (mm Hg); note, some manufactures reference as PCD.

E = Pollutant emission rate, ng/J (lb/million Btu).

E_a = Average pollutant rate for the specified performance test period, ng/J (lb/million Btu).

E_{ao}, E_{ai} = Average pollutant rate of the control device, outlet and inlet, respectively, for the performance test period, ng/J (lb/million Btu).

E_b = Pollutant rate from the steam generating unit, ng/J (lb/million Btu).

E_{bo} = Pollutant emission rate from the steam generating unit, ng/J (lb/million Btu).

E_c = Pollutant rate in combined effluent, ng/J (lb/million Btu).

E_{co} = Pollutant emission rate in combined effluent, ng/J (lb/million Btu).

E_d = Average pollutant rate for each sampling period (e.g.,24-hr Method 6B sample or 24-hr fuel sample) or for each fuel lot (e.g., amount of fuel bunkered), ng/J (lb/million Btu).

E_{di} = Average inlet SO_2 rate for each sampling period d, ng/J (lb/million Btu).

E_g = Pollutant rate from gas turbine, ng/J (lb/million Btu).

E_{ga} = Daily geometric average pollutant rate, ng/J (lbs/million Btu) or ppm corrected to 7 percent O_2.

E_{jo},E_{ji} = Matched pair hourly arithmetic average pollutant rate, outlet and inlet, respectively, ng/J (lb/million Btu) or ppm corrected to 7 percent O_2.

E_h = Hourly average pollutant, ng/J (lb/million Btu).

E_{hj} = Hourly arithmetic average pollutant rate for hour "j," ng/J (lb/million Btu) or ppm corrected to 7 percent O_2.

EXP = Natural logarithmic base (2.718) raised to the value enclosed by brackets.

Fc = Ratio of the volume of carbon dioxide produced to the gross calorific value of the fuel from Method 19

F_d, F_w, F_c = Volumes of combustion components per unit of heat content, scm/J (scf/million Btu).

ft^3 = cubic feet

G = ideal gas conversion factor

(385.23 SCF/lb-mol at 68 deg F & 14.696 psia)

GCM = gross Btu per SCF (constant, compound based)

GCV = Gross calorific value of the fuel consistent with the ultimate analysis, kJ/kg (Btu/lb).

GCV_p, GCV_r = Gross calorific value for the product and raw fuel lots, respectively, dry basis, kJ/kg (Btu/lb).

$\%_H$ = Concentration of hydrogen from an ultimate analysis of fuel, weight percent.

H_b = Heat input rate to the steam generating unit from fuels fired in the steam generating unit, J/hr (million Btu/hr).

H_g = Heat input rate to gas turbine from all fuels fired in the gas turbine, J/hr (million Btu/hr).

$\%_{H2O}$ = Concentration of water from an ultimate analysis of fuel, weight percent.

H_r = Total numbers of hours in the performance test period (e.g., 720 hours for 30-day performance test period).

K = volume of combustion component per pound of component (constant)

K = Conversion factor, 10^{-5} (kJ/J)/(%) [10^6 Btu/million Btu].

K_c = (9.57 scm/kg)/% [(1.53 scf/lb)/%].

K_{cc} = (2.0 scm/kg)/% [(0.321 scf/lb)/%].

K_{hd} = (22.7 scm/kg)/% [(3.64 scf/lb)/%].

K_{hw} = (34.74 scm/kg)/% [(5.57 scf/lb)/%].

K_n = (0.86 scm/kg)/% [(0.14 scf/lb)/%].

K_o = (2.85 scm/kg)/% [(0.46 scf/lb)/%].

K_s = (3.54 scm/kg)/% [(0.57 scf/lb)/%].

K_{sulfur} = $2x10^4$ Btu/wt%-MMBtu

K_w = (1.30 scm/kg)/% [(0.21 scf/lb)/%].

lb = pound

ln = Natural log of indicated value.

L_p,L_r = Weight of the product and raw fuel lots, respectively, metric ton (ton).

$\%_N$ = Concentration of nitrogen from an ultimate analysis of fuel, weight percent.

$M_{\%}$ = mole percent

mol = mole

MW = molecular weight (lb/lb-mol)

MW_{AIR} = molecular weight of air (28.9625 lb/lb-mole)[1]

NCM = net Btu per SCF (constant based on compound)

$\%_O$ = Concentration of oxygen from an ultimate analysis of fuel, weight percent.

$\%_{O2d}$, $\%_{O2w}$ = Concentration of oxygen on a dry and wet basis, respectively, percent.

P_B = barometirc pressure, in Hg

P_s = Potential SO2 emissions, percent.

$\%_S$ = Sulfur content of as-fired fuel lot, dry basis, weight percent.

S_e = Standard deviation of the hourly average pollutant rates for each performance test period, ng/J (lb/million Btu).

$\%_{SI}$ = Concentration of sulfur from an ultimate analysis of fuel, weight percent.

S(wt%) = weight percent of sulfur, per lab analysis by appropriate ASTM standard

S_i = Standard deviation of the hourly average inlet pollutant rates for each performance test period, ng/J (lb/million Btu).

S_o = Standard deviation of the hourly average emission rates for each performance test period, ng/J (lb/million Btu).

$\%S_p$, $\%S_r$ = Sulfur content of the product and raw fuel lots respectively, dry basis, weight percent.

SCF = standard cubic feet

SH = specific humidity, pounds of water per pound of air

$t_{0.95}$ = Values shown in Table 19-3 for the indicated number of data points n.

T_{amb} = ambient temperature, °F

W/D Factor = 1.0236 = conv. at 14.696 psia and

68 deg F (ref. Civil Eng. Ref. Manual, 7th Ed.)

X_{CO2}=CO_2 Correction factor, percent.

X_k = Fraction of total heat input from each type of fuel k.

Calculations, Formulas, and Constants

The following information supports the spreadsheets for this testing project.

Given Data:

Ideal Gas Conversion Factor = 385.23 SCF/lb-mol at 68 deg F & 14.696 psia

Fuel Heating Value is based upon Air Hygiene's fuel gas calculation sheet. All calculations are based upon a correction to 68 deg F & 14.696 psia

High Heating Values (HHV) are used for the Fuel Heating Value, F-Factor, and Fuel Flow Data per EPA requirements.

ASTM D 3588

Molecular Weight of NOx (lb/lb-mole) =	46.01
Molecular Weight of CO (lb/lb-mole) =	28.00
Molecular Weight of SO2 (lb/lb-mole) =	64.00
Molecular Weight of THC (propane) (lb/lb-mole) =	44.00
Molecular Weight of VOC (methane) (lb/lb-mole) =	16.00
Molecular Weight of NH3 (lb/lb-mole) =	17.03
Molecular Weight of HCHO (lb/lb-mole) =	30.03

40CFR60, App. A., RM 19, Table 19-1

Conversion Constant for NOx =	0.0000001194351
Conversion Constant for CO =	0.0000000726839
Conversion Constant for SO2 =	0.0000001661345
Conversion Constant for THC =	0.0000001142175
Conversion Constant for VOC (methane) =	0.0000000415336
Conversion Constant for NH_3 =	0.0000000442074
Conversion Constant for HCHO =	0.0000000779534

NOTE: units are lb/ppm*ft^3

Formulas:

1. Corrected Raw Average (C_{Gas}), 40CFR60, App. A, RM 7E, Eq. 7E-5 (08/15/06)

$$C_{Gas} = (C_{Avg} - C_O) \times \left(\frac{C_{MA}}{C_M - C_O} \right)$$

2. Correction to % O_2, 40CFR60, App. A, RM 20, Eq. 20-5 (11/26/02)

$$C_{adj} = C_{Gas\,(Target)} \times \left(\frac{20.9\% - AdjFactor}{20.9\% - C_{Gas\,(O2)}} \right)$$

3. Emission Rate in lb/hr

$$E_{lb/hr} = \frac{C_{Gas}}{10^6} \times \frac{Q_S \times MW}{G}$$

4. Emission Concentration in lb/MMBtu (O_2 based)

$$E_{lb/MMBtu} = \frac{C_{Gas} \times F_d Factor \times Conv_C \times 20.9\%}{20.9\% - C_{Gas\,(O2)}}$$

5. Emission Concentration in lb/MMBtu (CO_2 based)

$$E_{lb/MMBtu} = \frac{C_{Gas} \times F_d Factor \times Conv_C \times 100\%}{C_{Gas\,(CO2)}}$$

RATA SHEET CALCULATIONS

d = Reference Method Data - CEMS Data

S_d = Standard Deviation

CC = Confident Coefficient

n = number of runs

$t_{0.025}$ = 2.5 percent confidence coefficent T-values

RA = relative accuracy

ARA = alternative relative accuracy

BAF = Bias adjustment factor

n	t	n	t	n	t
2	12.706	7	2.447	12	2.201
3	4.303	8	2.365	13	2.179
4	3.182	9	2.306	14	2.160
5	2.776	10	2.262	15	2.145
6	2.571	11	2.228	16	2.131

1. Difference

$$d = \sum_{i=1}^{n} d_i$$

2. Standard Deviation

$$S_d = \sqrt{\frac{\sum_{i=1}^{n} d_i^2 - \left[\frac{\left(\sum_{i=1}^{n} d_i \right)^2}{n} \right]}{n-1}}$$

3. Confident Coefficient

$$CC = t_{0.025} \times \frac{S_d}{\sqrt{n}}$$

4. Relative Accuracy

$$RA = \frac{|d_{AVG}| + |CC|}{RM_{AVG}} \times 100$$

5. Alternative Relative Accuracy

$$ARA = \frac{|d_{AVG}| + |CC|}{AS} \times 100$$

5. Bias Adjustment Factor

$$BAF = 1 + \left(\frac{|d_{AVG}|}{CEM_{AVG}} \right)$$

APPENDIX D

STATEMENT OF QUALIFICATIONS

AIR HYGIENE E'MISSION Statement:

AIR HYGIENE's core philosophy of "**Second-to-None (2-2-0)**", demands extra mile customer service anchored on dignified character and family-oriented principles to deliver unmatched quality stack testing, worth paying for every time. We utilize revolutionary technology and AIR HYGIENE UNIVERSITY to create the best educated work force to define the future of stack testing.

STATEMENT OF QUALIFICATIONS

AIR HYGIENE

AIR EMISSION TESTING SERVICES
January, 2019

INTRODUCTION

AIR HYGIENE INTERNATIONAL, INC. (AIR HYGIENE) is a professional air emission testing services firm operating from corporate headquarters in Broken Arrow, Oklahoma for 20 years. Additional field offices with ready for field use testing labs are strategically located in Las Vegas, Nevada; Austin and Ft. Worth, Texas; Shreveport, Louisiana; Chicago, Illinois; and Pittsburgh, Pennsylvania to serve all fifty (50) United States, Mexico, and Canada. AIR HYGIENE specializes in air emission testing services for combustion sources burning multiple fuels with multiple control devices and supporting equipment.

AIR HYGIENE testing laboratories are equipped with the following capabilities:

1. State-of-the-Art air emission analyzers, computers, and data-logging software!
2. Dual racks for multiple source testing simultaneously or multiple points on a single source (in/out SCR, etc.)!
3. NIST traceable gases for the most accurate calibration. Ranges as low as five (5) ppm!
4. PM_{10}, NH_3, mercury (Hg), sulfuric acid mist (H_2SO_4), SO_3, and formaldehyde sampling equipment!
5. VOC testing with on-board gas chromatograph to remove methane and ethane!
6. On-board printers to provide hard copies of testing information on-site!
7. Networking capabilities to provide real-time emission data directly into the control room!

AIR HYGIENE is known for providing professional services which include the following:

- Superior cost effective services to our clients!
- Educated work force trained to utilize the latest in revolutionary technology!
- Meeting our client's needs whether it is 24 hour a day testing or short notice mobilization!
- Using great equipment that is maintained and dependable!
- Understanding the unique start-up and operational needs associated with combustion sources!
- Experience working with state and federal regulations and agencies in all 50 states!

OUR MISSION

Our mission is to provide innovative, practical, top-quality services allowing our clients to increase operating efficiency, save money, and comply with federal and state requirements. We believe our first responsibility is to the client. In providing our unique services, the owners of AIR HYGIENE demand ethical conduct from each employee of the company. The character and integrity of AIR HYGIENE employees allows our clients to feel confident in the air testing services of AIR HYGIENE. Through a long-term commitment to this mission, AIR HYGIENE is known as a company committed to improving our clients' operations.

TESTING EXPERIENCE

AIR HYGIENE has **twenty-six (26) QSTI certified** personnel on staff and more than two hundred (200) years of combined testing experience. We have completed over 25,000 emission tests and our testing services history includes interaction with all 50 state agencies and EPA regional offices. AIR HYGIENE testing personnel are rigorously trained through our very own AIR HYGIENE UNIVERSITY on EPA reference test methods from 40 CFR Part 51, 60, 63, and 75 along with ASTM methods. All testing personnel are instructed and tested on test responsibilities and must complete a "Demonstration of Capability" test per the AIR HYGIENE Quality Assurance Manual and the AIR HYGIENE Emission Testing Standard OperatingProcedures Handbook.

AIR HYGIENE has completed testing on over 500 power plants including in excess of 2,500 combustion turbines and 100 coal fired boilers 250,000 megawatts (MW). ***Let us add your project to our list of satisfied customers!***

TESTING SUCCESS STORIES

AIR HYGIENE personnel have performed thousands of testing projects which have yielded significant benefits for our clients. The following project descriptions briefly discuss some of these emission testing projects.

- Conducted Mercury (Hg), PM, selected metals, HCl, Chlorine, and gas testing to verify status with the industrial boiler MACT on six coal fired units at three (3) locations.
- Conducted inlet/outlet baghouse emission testing for Mercury (Hg) to determine control efficiency using Ontario-Hyrdo testing methodology.
- Conducted numerous projects optimizing SCR performance by conducting inlet & outlet SCR analysis for NH_3, NO_x, flow, and Oxygen. Used information to assist with flow optimization and AIG tuning.
- Conducted federal and state required compliance testing for NO_x, CO, PM-10 (front & back-half), SO_2, VOC, Ammonia, Formaldehyde, Opacity, RATA testing (NO_x and CO) for new and updated power plants with both simple and combined cycle turbines firing natural gas and fuel oil.
- Conducted dry low NO_x burner tuning and performance testing for various models of GE, Siemens Westinghouse, Mitsubishi, Pratt & Whitney, and ABB combustion turbines to verify manufacturer's emission guarantees for clients in preparation for compliance testing.
- Performed power plant emission testing for natural gas & fuel oil fired combustion turbines. Tests included federal required testing per 40 CFR Part 75, state air permit requirements, RATA testing, and emission testing to verify manufacturer's guarantees during electric/heat output performance testing.

TESTING LOCATIONS

AIR HYGIENE bases mobilization charges on the distance from your site to the closest of seven (7) regional starting points covering all 50 United States. These include Broken Arrow, Las Vegas, Austin, Ft. Worth, Shreveport, Chicago and Pittsburgh.

Each start point is located such that the AIR HYGIENE test teams can mobilize to your site within 24 hours at affordable costs to ensure we are price competitive to any U.S. location.



QUALITY ASSURANCE PROGRAM SUMMARY

Air Hygiene has received interim accreditation from the Source Testing Accreditation Council (STAC) per ASTM D7036 as an Air Emission Testing Body (AETB). Air Hygiene also maintains current accreditation from LDEQ, CARB, SCAQMD, and PADEP.

Air Hygiene has **twenty-six (26) Qualified Stack Testing Individuals (QSTI)** on staff providing testing leadership for every testing project; including a PhD Chemical Engineer who is ACS Certified managing in house laboratory operations and specialty remote wet chemistry projects.

Air Hygiene ensures the quality and validity of its emission measurement and reporting procedures through a rigorous quality assurance (QA) program. The program is developed and administered by an internal QA team and encompasses five major areas:

1. QA reviews of reports, laboratory work, and field testing;
2. Equipment calibration and maintenance;
3. Chain-of-custody;
4. Training; and
5. Knowledge of current test methods.

QA Reviews

Air Hygiene's review procedure includes review of each source test report, along with laboratory and fieldwork, by the QA Team. The most important review is the one that takes place before a test program begins. The QA Team works closely with technical division personnel to prepare and review test protocols. Test protocol review includes selection of appropriate test procedures, evaluation of interferences or other restrictions that might preclude use of standard test procedures, and evaluation and/or development of alternate procedures.

Equipment Calibration and Maintenance

The equipment used to conduct the emission measurements is maintained according to the manufacturer's instructions to ensure proper operation. In addition to the maintenance program, calibrations are carried out on each measurement device according to the schedule outlined by the Environmental Protection Agency. Quality control checks are also conducted in the field for each test program. Finally, Air Hygiene participates in a PT gas program by analyzing blind gases semi-annually to ensure continued quality.

Chain-of-Custody

Air Hygiene maintains full chain-of-custody documentation on all samples and data sheets. In addition to normal documentation of changes between field sample custodians, laboratory personnel, and field test personnel, Air Hygiene documents every individual who handles any test component in the field (e.g., probe wash, impinger loading and recovery, filter loading and recovery, etc.). Samples are stored in a locked area to which only Air Hygiene personnel have access. Field data sheets are secured at Air Hygiene's offices upon return from the field.

Training

Training available to both employees and customers through our very own Air Hygiene University is essential to ensure quality testing. Constantly striving to be recognized globally as the worldwide leader in Stack Testing Training, Air Hygiene University has developed a baseline foundation and curriculum using a unique indoor training facility, practice stack, and over 16 years of real-world field testing experience. Air Hygiene University's classwork combines customized training modules focusing on presentation, testing, resource utilization, and hands-on experience and the knowledge from each module can be combined to provide a final capstone, a Demonstration of Competency in the subject matter of interest. Participants are prepared to pass the Qualified Individual examinations and obtain Federal certifications and have the ability to apply new and refreshed knowledge about each test method to everyday work practices.

Knowledge of Current Test Methods

With the constant updating of standard test methods and the wide variety of emerging test procedures, it is essential that any qualified source tester keep abreast of new developments. Air Hygiene subscribes to services, which provide updates on EPA reference methods, rules, and regulations. Additionally, source test personnel regularly attend and present papers at testing and emission-related seminars and conferences.

TESTING QUALITY ASSURANCE ACTIVITIES

A number of quality assurance activities are undertaken before, during, and after turbine testing projects. This section describes each of those activities.

Each instrument's response is checked and adjusted in the field prior to the collection of data via multi-point calibration. The instrument's linearity is checked by first adjusting its zero and span responses to zero nitrogen and an upscale calibration gas in the range of the expected concentrations. The instrument response is then challenged with other calibration gases of known concentration and accepted as being linear if the response of the other calibration gases agreed within ± two percent of range of the predicted values.

NO_2 to NO conversion is checked via direct connect with an EPA Protocol certified concentration of NO_2 in a balance of nitrogen. Conversion is verified to be above 90 percent.

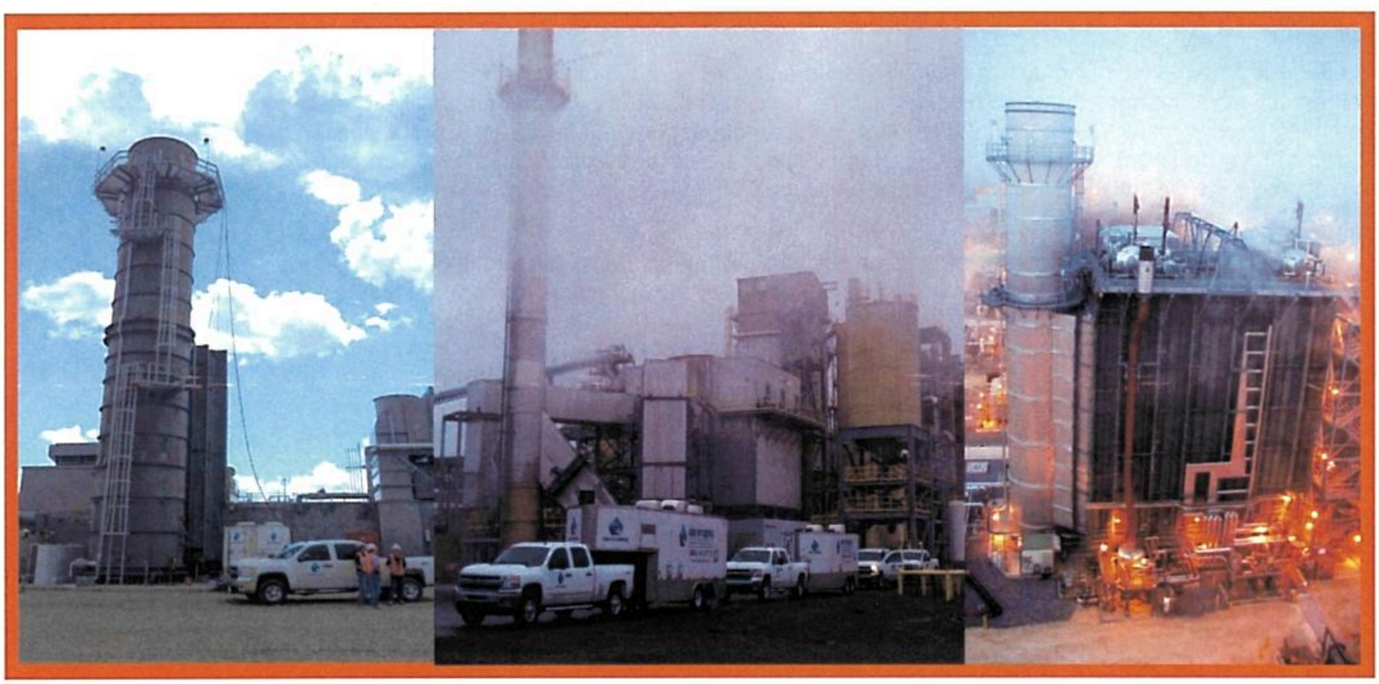
Instruments are both factory- tested and periodically field challenged with interference gases to verify the instruments have less than a two percent interference from CO_2, SO_2, CO, NO, and O_2.

After each test run, the analyzers are checked for zero and span drift. This allows each test run to be bracketed by calibrations and documents the precision of the data collected. The criterion for acceptable data is that the instrument drift is no more than three percent of the full-scale response. Quality assurance worksheets summarize all multipoint calibration linearity checks and the zero to span checks performed during the tests are included in the test report.

The sampling systems is leak checked by demonstrating that a vacuum greater than 10 in. Hg can be held for at least one minute with a decline of less than 1 in. Hg. A leak test is conducted after the sample system is set up and before the system is dismantled. This test is conducted to ensure that ambient air does not dilute the sample. Any leakage detected prior to the tests is repaired and another leak check conducted before testing will commence.

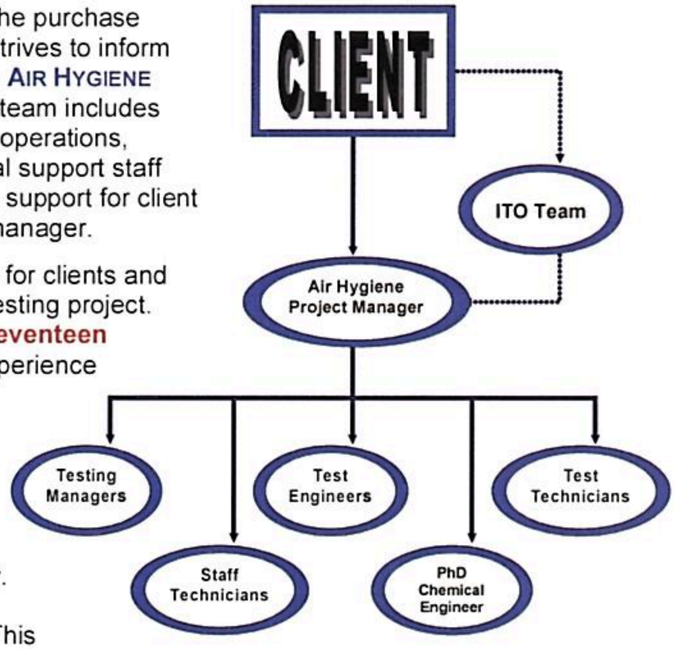
The absence of leaks in the sampling system is also verified by a sampling system bias check. The sampling system's integrity is tested by comparing the responses of the analyzers to the responses of the calibration gases introduced via two paths. The first path is directly into the analyzers and the second path includes the complete sample system with injection at the sample probe. Any difference in the instrument responses by these two methods is attributed to sampling system bias or leakage. The criterion for acceptance is agreement within five percent of the span of the analyzer.

The control gases used to calibrate the instruments are analyzed and certified by the compressed gas vendors to ± one percent accuracy for all gases. EPA Protocol No.1 is used, where applicable, to assign the concentration values traceable to the National Institute of Standards and Technology (NIST), Standard Reference Materials (SRM). The gas calibration sheets as prepared by the vendor are included in the test report.



EMISSION TESTING TEAM

Air Hygiene International, Inc. (AIR HYGIENE) intends to exceed your expectations on every project. From project management to field-testing teams, we're committed to working hard on your behalf. The job descriptions and flow chart below outline AIR HYGIENE's client management strategy for your testing services.



From the initial request through receipt of the purchase order, the Inquisition to Order (ITO) team strives to inform every client of the benefits gained by using AIR HYGIENE for their emission testing project. The ITO team includes representatives from the sales, marketing, operations, and contracts divisions. In addition, several support staff assist to ensure the ITO team provides the support for client needs as requested by a client or project manager.

Project Managers are the primary contact for clients and ultimately responsible for every emission testing project. AIR HYGIENE's Project Managers include **seventeen (17) QSTI certified** testing experts with experience ranging from those with a masters level, to professional engineers to industry experts with over 25,000 testing projects completed. Each project is assigned a Project Manager based primarily upon geographic location, industry experience, contact history, and availability. The Project Manager prepares the testing strategy and organization for the project. This includes preparation of testing protocol; coordination with state agencies, client representatives, and any interested third parties. The site testing and report preparation are executed under the direction of the Project Manager from start to finish.

Testing Managers have completed Air Hygiene's rigorous demonstration of capability training program and are capable of operating all testing equipment and performing all test methods required for your testing project. Testing Managers assist Project Managers by leading the field testing when required, preparing draft reports, calibrating equipment, and overseeing the testing team on-site. AIR HYGIENE's staff includes **seven (7) QSTI certified** testing managers.

Test Engineers have significant background and understanding of emission testing or related services. Test Engineers prepare pre-test drawings for port location, ensure on-site logistics for electrical and mechanical/structural needs, and conduct on-site testing as directed by the Project Manager and/or Testing Manager. Test Engineers often have special understanding of process and/or regulations applicable to specific testing jobs, which provide great value to both the client and Project Manager in testing strategies. AIR HYGIENE's staff includes **two (2) QSTI certified** testing managers.

Test Technicians experience ranges from new hire with technical degree and experience to technicians who have performed 500 emission tests. All test technicians have a basic understanding of emission training and are involved in daily training and under supervision to continue to develop testing skills. Each has testing experience with AIR HYGIENE equipment along with a variety of industries and source equipment. Test Technicians may operate isokinetic sampling trains or gas analyzers on-site under the direction of the Project Manager and assist with preparation of field reports and quality assurance procedures.

Staff Technicians are entry-level personnel who have performed fewer than 500 emission tests. Staff Technicians perform pre-test equipment preparation, on-site test preparation, and testing assistance under the direction of Project Manager and/or Testing Manager. Staff Technicians connect sampling probes to ports, raise and lower equipment to and from sampling platform, and other support activities under the direction of the Project Manager and/or Testing Manager.

PhD Chemical Engineer/Lab Manager our in house, ACS Certified Lab Manager manages in house laboratory operations and is available for specialty remote wet chemistry projects on site to provide added expertise and accuracy.

Accredited Laboratory

A2LA has accredited

AIR HYGIENE INTERNATIONAL, INC.

Broken Arrow, OK

for technical competence in the field of

Environmental Testing

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2005 *General requirements for the competence of testing and calibration laboratories*. This laboratory also meets the R219 – Specific Requirements – TNI Field Sampling and Measurement Organization Accreditation Program. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (*refer to joint ISO-ILAC-IAF Communiqué dated 8 January 2009*).

AMERICAN ASSOCIATION FOR LABORATORY ACCREDITATION
CORPORATE SEAL 1978 DISTRICT OF COLUMBIA
A2LA

Presented this 10th day of October 2017

President and CEO
For the Accreditation Council
Certificate Number 3796.01
Valid to August 31, 2019

For the types of tests to which this accreditation applies, please refer to the laboratory's Environmental Scope of Accreditation.

STAC
STACK TESTING ACCREDITATION COUNCIL

American Association for Laboratory Accreditation

Accredited Air Emission Testing Body

A2LA has accredited

AIR HYGIENE INTERNATIONAL, INC.

In recognition of the successful completion of the joint A2LA and Stack Testing Accreditation Council (STAC) evaluation process, this laboratory is accredited to perform testing activities in compliance with ASTM D7036:2004 - Standard Practice for Competence of Air Emission Testing Bodies.

Presented this 10th day of October 2017

President and CEO
For the Accreditation Council
Certificate Number 3796.02
Valid to August 31, 2019

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40 CFR 60, SUBPART OOOOa
EMISSIONS TESTING PROTOCOL

FOR
ONE ENCLOSED COMBUSTOR

PREPARED FOR
CIMAREX

AT THE
LEHMAN COM 7-11H FACILITY
WATONGA, OKLAHOMA

Oklahoma Department of Environmental Quality
Permit No: 2018-1031-O
Source Classification Code (SCC): 31000205

August 15, 2019

Corporate Headquarters
1600 W Tacoma Street
Broken Arrow, OK 74012

AIR HYGIENE, INC.
(918) 307-8865 or (888) 461-8778
www.airhygiene.com

Remote Testing Offices
Las Vegas, NV 89156
Ft. Worth, TX 76028
Humble, TX 77338
Shreveport, LA 71115
Miami, FL 33101
Pittsburgh, PA 15205

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Prepared By:

Nathan Arthur

Nathan Arthur, QSTI, Sr. Manager – Test Protocols

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1.0 INTRODUCTION

1.1 General Facility Description

Cimarex (Cimarex) owns and operates the Lehman COM 7-11H facility located in Blaine County, Oklahoma. Located on the facility is one Enclosed Combustor, designated as Combustor 2. The interest of this protocol is Combustor 2.

The Combustor 2 stack is vertical, circular in orientation. The test port locations meet the minimum EPA Method 1 requirement of at least 0.5 duct diameters (dd) upstream and 2.0 dd downstream from the nearest disturbances. All stack dimension measurements will be taken and verified in the field prior to the beginning of testing.

1.2 Reason for Testing

The unit is subject to emission testing requirements set forth in the standards designated by the United States Environmental Protection Agency (EPA) Title 40, Code of Federal Regulations, Part 60 (40CFR60), Subpart OOOOa and the Oklahoma Department of Environmental Quality (ODEQ) operating permit (2018-1031-O); and to the limits specified in Table 1.2. As such, the unit will be tested for total organic compounds (TOC) and oxygen (O_2) with the unit operating at the maximum combustion rate (MCR).

TABLE 1.2
EMISSION LIMITS

Target	Permit Limits
TOC	275 ppmvw@3%O_2

2.0 SUMMARY

2.1 Site Information

Site:	Lehman COM 7-11H Facility
Contact Person:	Marcia Ortiz
Office:	(918) 560-7290
Cell:	(918) 805-6330
Email:	MOrtiz@cimarex.com
Latitude, Longitude:	35.7836825, -98.3379311

2.2 Test Contractor Information

Company:	Air Hygiene International, Inc.
Contact Person:	Danny Parr, Director of Operations
Mailing Address:	1600 W Tacoma Street Broken Arrow, Oklahoma 74012
Office:	(918) 307-8865
Cell:	(918) 809-8947
Fax:	(918) 307-9131
E-mail:	danny@airhygiene.com
Website:	www.airhygiene.com
AETB Certificate No:	3796.02
ISO/IEC Certificate No:	3796.01

2.3 Expected Test Start Date

Testing is anticipated to begin on October 8, 2019. Notification of changes will be made by Cimarex, as necessary.

2.4 Testing Schedule

The following schedule indicates specific activities required to be done each day; however, the schedule may require flexibility and will be compacted or extended as necessary.

Pre-test Activities	**Due Date**
1. Prepare draft test protocol (Air Hygiene)	prior to testing

Compliance Testing	**Time**
Day 1 – Combustor 2	
• Daily setup and calibrations	14:00 – 15:00
• Conduct testing for TOC and O_2 • TOC and O_2 testing: 3, 60-minute runs	15:00 – 19:00
• Teardown and prepare to demobilize	19:00 – 20:00

Activities after Testing	
• Demobilization of Testing Crew (Air Hygiene)	Day 1
• Preparation of draft test report (Air Hygiene)	Days 2 – 9
• Submit for review to Cimarex (Air Hygiene)	Day 10
• Review and comment on draft (Cimarex)	Days 11 – 15
• Prepare final hard copy test reports (Air Hygiene)	Days 16 – 19
• Final reports delivered to Cimarex (Air Hygiene)	Day 20

2.5 Test Report Content

The Test Report for the unit will meet the requirements of the ODEQ and the EPA for compliance and certification testing. The report will include discussion of the following:

- Introduction
- Plant and Sampling Location Description
- Summary and Discussion of Test Results Relative to Acceptance Criteria
- Sampling and Analytical Procedures
- QA/QC Activities
- Test Results and Related Calculations
- Stack and Testing Equipment Drawings
- Raw Field Data and Calibration Data Sheets
- Sampling Log and Chain-of-Custody Records
- Audit Data Sheets

2.6 Equipment and Procedures

Test methods and parameters to satisfy 40 Code of Federal Regulations (CFR) Part 60 and will include:

- 40 CFR 60, App A, EPA Method 1 for sample location
- 40 CFR 60, App A, EPA Method 3A for oxygen (O_2)
- 40 CFR 60, App A, EPA Method 25A for total hydrocarbons (TOCs)

2.7 Proposed Variations

TOC testing will be conducted from a single point near the center of the stack. No pre-test stratification test will be conducted.

No bias correction will be utilized for the EPA Method 25a sampling and all negative readings will be replaced with "zeroes" prior to determining final averages. Also, the TOC analyzer will be calibrated by running the certified gases through the sample probe, rather than directly to the back of the analyzer.

2.8 Compliance Sampling Strategy

Testing will be conducted on the unit for total organic compounds (TOC) and oxygen (O_2) with the unit operating at the maximum combustion rate (MCR).

Testing on the combustors will include:

- TOCs – 3 test runs at 1 hour per run
- O_2 – 3 test runs at 3 hours per run

During testing Cimarex personnel will track relevant unit operating parameters. Air Hygiene personnel will monitor and record ambient temperature (°F), relative humidity (%), and barometric pressure (in. Hg) at the start of each test run.

Method 3A and 25A – Oxygen and Total Organic Compound Testing
Refer to Appendix B for additional details.

APPENDIX A

QA/QC PROGRAM

QA/QC PROGRAM

AIR HYGIENE ensures the quality and validity of its emission measurement and reporting procedures through a rigorous quality assurance (QA) program. The program is developed and administered by an internal QA team and encompasses six major areas:

1. Field Qualifications
2. QA reviews of reports, laboratory work, and field testing;
3. Equipment calibration and maintenance;
4. Chain-of-custody;
5. Training; and
6. Knowledge of current test methods

Field Qualifications

Air Hygiene personnel are required to gain and maintain competence with testing methods and techniques according to their job titles and the roles they play during field testing events. Qualifications for each job description include:

Staff Technician - An entry level position with responsibility to test on the stack by performing duties that include: keep trucks and trailers stocked and clean, travel to and from job site, be the "hands of the test" on the stack; stay on a stack during the sample test, set up and tear down equipment on-site, perform maintenance on equipment in the shop and on-site.

Test Technician or Specialist - Acts as the "hands of the test" on the stack by performing duties that include: stay on a stack during the sample test, migrate to the testing trailer and learn the different analyzers and testing methods used on site, set up and tear down testing equipment on site, learn the system for testing from Testing Managers and Project Managers, travel to and from job site; including driving responsibilities under DOT requirements, follow directions of Testing Managers and Project Managers, learn the proper way to conduct on-site test of stationary stacks

Test Manager or Engineer - Directs and coordinates all aspects of a successful test by performing the following duties personally or through subordinate supervisors including: operating analyzers and consoles during testing along with QA/QC procedures, supervise set up and tear down of equipment on site, writing, reviewing, and revising final test reports, working with the client or state personnel while on the job site, managing pre-test checklists and onsite testing procedures, diagnose and repair any problems that may arise with the equipment, safely operate a man lift and drive a truck with or without a trailer, act as crew leader in the field, write protocols and reports, maintain project log of services performed on the job, verify all equipment needed for a job was loaded on the trailer. Test Managers must hold as least one QSTI certificate.

Project Manager - Directs and coordinates all aspects of a successful test by performing the following duties personally or through subordinate supervisors including: operating analyzers and consoles during testing along with QA/QC procedures, supervise set up and tear down of equipment on site, writing, reviewing, and revising final test reports, working with the client or state personnel while on the job site, managing pre-test checklists and onsite testing procedures, diagnose and repair any problems that may arise with the equipment, safely operate a man lift and drive a truck with or without a trailer, act as crew leader in the field, write protocols and reports, maintain project log of services performed on the job, verify all equipment needed for a job was loaded on the trailer. Project Managers typically hold QSTI certificates in Groups 1 through 4.

QA Reviews

AIR HYGIENE's review procedure includes a review of each source test report, along with laboratory and fieldwork by the QA Team.

The most important review is the one that takes place before a test program begins. The QA Team works closely with technical division personnel to prepare and review test protocols. Test protocol review includes selection of appropriate test procedures, evaluation of interferences or other restrictions that might preclude use of standard test procedures, and evaluation and/or development of alternate procedures.

Equipment Calibration and Maintenance

The equipment used to conduct the emission measurements is maintained according to the manufacturer's instructions to ensure proper operation. In addition to the maintenance program, calibrations are carried out on each measurement device according to the schedule outlined by the Environmental Protection Agency. Quality control checks are also conducted in the field for each test program.

Chain-of-Custody

AIR HYGIENE maintains full chain-of-custody documentation on all samples and data sheets. In addition to normal documentation of changes between field sample custodians, laboratory personnel, and field test personnel, AIR HYGIENE documents every individual who handles any test component in the field (e.g., probe wash, impinger loading and recovery, filter loading and recovery, etc.). Samples are stored in a locked area to which only AIR HYGIENE personnel have access. Field data sheets are secured at AIR HYGIENE's offices upon return from the field. Per standard Air Hygiene policy, laboratory samples will be discarded after 30 days of receipt of final report unless otherwise specified in writing.

Training

Personnel training is essential to ensure quality testing. AIR HYGIENE has formal and informal training programs, which include:

1. Attendance at EPA-sponsored training courses;
2. Enrollment in EPA correspondence courses;
3. A requirement for all technicians to read and understand Air Hygiene Incorporated's QA manual;
4. In-house training and QA meetings on a regular basis; and
5. Maintenance of training records.

Knowledge of Current Test Methods

With the constant updating of standard test methods and the wide variety of emerging test procedures, it is essential that any qualified source tester keep abreast of new developments. AIR HYGIENE subscribes to services, which provide updates on EPA reference methods, rules, and regulations. Additionally, source test personnel regularly attend and present papers at testing and emission-related seminars and conferences.

COMBUSTION TESTING QUALITY ASSURANCE ACTIVITIES

A number of quality assurance activities are undertaken before, during, and after each testing project. The following paragraphs detail the quality control techniques, which are rigorously followed during testing projects.

Each instrument's response will be checked and adjusted in the field prior to the collection of data via multi-point calibration. The instrument's linearity will be checked by first adjusting its zero and span responses to zero nitrogen and an upscale calibration gas in the range of the expected concentrations. The instrument response will then be challenged with other calibration gases of known concentration and accepted as being linear if the response of the other calibration gases agrees within plus or minus 2 percent of range of the predicted values.

After each test run, the analyzers will be checked for zero and span drift. This allowed each test run to be bracketed by calibrations and documents the precision of the data just collected. The criteria for acceptable data are that the instrument drift is no more than 3 percent of the full-scale response. Quality assurance worksheets will be prepared to document the multipoint calibration checks and zero to span checks performed during the tests.

The sampling systems will be leak checked by demonstrating that a vacuum greater than 10 in Hg can be held for at least 1 minute with a decline of less than 1 in. Hg. A leak test will be conducted after the sample system is set up and before the system is dismantled. This test will be conducted to ensure that ambient air has not diluted the sample. Any leakage detected prior to the tests will be repaired and another leak check conducted before testing commences.

The absence of leaks in the sampling system will also be verified by a sampling system bias check. The sampling system's integrity will be tested by comparing the responses of the analyzers to the calibration gases introduced via two paths. The first path will be directly into the analyzer and the second path will be via the sample system at the sample probe. Any difference in the instrument responses by these two methods will be attributed to sampling system bias or leakage. The criteria for acceptance will be agreement within 5 percent of the span of the analyzer.

The control gases used to calibrate the instruments will be analyzed and certified by the compressed gas vendors to ± 1% accuracy for all gases. EPA Protocol No. 1 will be used where applicable to assign the concentration values traceable to the National Institute of Standards and Technology (NIST), Standard Reference Materials.

AIR HYGIENE maintains a large variety of calibration gases to allow the flexibility to accurately test emissions over a wide range of concentrations.

APPENDIX B

TEST EQUIPMENT CONFIGURATION AND DESCRIPTION

INSTRUMENT CONFIGURATION AND OPERATIONS FOR GAS ANALYSIS

The sampling and analysis procedures to be used conform with the methods outlined in the Code of Federal Regulations, Title 40, Part 60, Appendix A, Methods 1, 3A, and 25A.

The sample system to be used for the real-time gas analyzer tests is configured per the following description. A stainless steel probe will be inserted near the center of the stack. The gas sample will be continuously pulled through the probe and transported via 3/8-inch heat-traced Teflon® tubing to a stainless steel, minimum-contact condenser designed to dry the sample and then through Teflon® tubing via a stainless steel/Teflon® diaphragm pump and into the sample manifold within the mobile laboratory. From the manifold, the sample is partitioned to the real-time gas analyzer through rotameters that control the flow rate of the sample. Exhaust samples are routed to the wet based analyzer prior to gas conditioning.

The schematic (Figure 1) shows that the sample system is also equipped with a separate path through which a calibration gas could be delivered to the probe and back through the entire sampling system. This allows for convenient performance of system bias checks as required by the testing methods.

All instruments are housed in an air-conditioned, trailer-mounted mobile laboratory. Gaseous calibration standards are provided in aluminum cylinders with the concentrations certified by the vendor according to EPA Protocol No. 1.

This general schematic also illustrates the analyzers to be used for the tests (i.e., O_2). All data from the Reference Method continuous monitoring instruments are recorded on a Logic Beach Hyperlogger. The Hyperlogger retrieves calibrated emissions data from each instrument every second. An average value is recorded every 30 seconds.

The stack gas analysis for O_2 concentrations will be performed in accordance with procedures set forth in EPA Method 3A. The O_2 analyzer uses a paramagnetic cell detector.

TOC emission concentrations will be quantified in accordance with principles set forth in EPA Method 25a. A flame ionization detector FID will be used for the measurements. This detector responds to all hydrocarbons in the sample. Total hydrocarbon results will be assumed as TOCs.

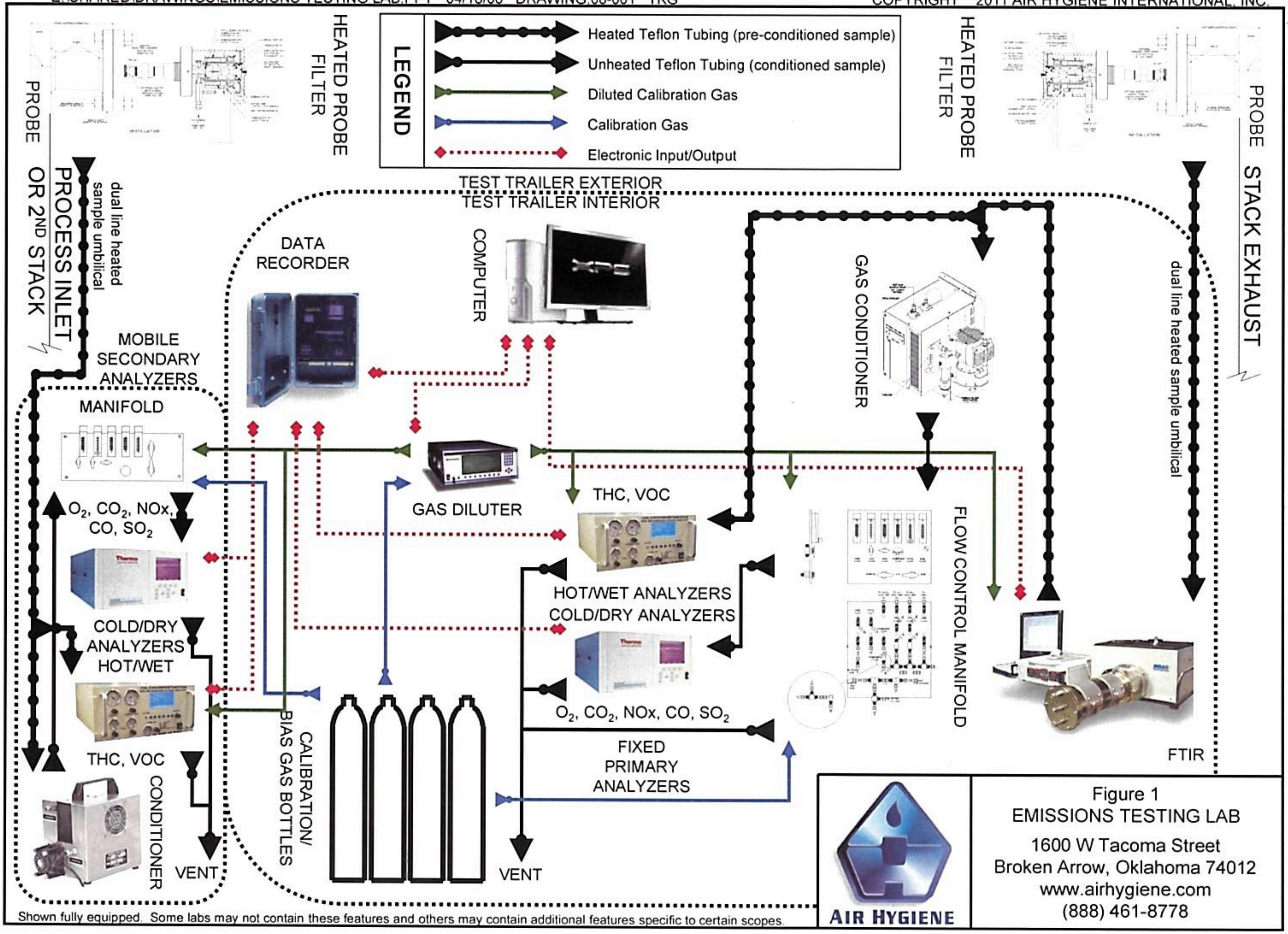


Figure 1
EMISSIONS TESTING LAB

1600 W Tacoma Street
Broken Arrow, Oklahoma 74012
www.airhygiene.com
(888) 461-8778

TABLE 1: TESTING MATRIX

Target	EPA Test Method	Locations/Unit Test Load(s)	Test Length
O_2	3A	Combustor / Maximum	3, 60-minute test runs
TOC	25A	Combustor / Maximum	3, 60-minute test runs

TABLE 2: ANALYTICAL INSTRUMENTATION

Parameter	Model and Manufacturer	Common Use Ranges	Sensitivity	Detection Principle
O_2	Servomex or equivalent	0-25%	0.1%	Oxygen - Paramagnetic cell
TOC	TECO 51 or equivalent	User may select up to 3,000 ppm	0.1 ppm	Flame Ionization Detector

TABLE 3: ANALYTICAL INSTRUMENTATION TESTING CONFIGURATION

Parameter	Sample Methodology	Example Range	Calibration Gases (based on example range)
O_2	3A	0-21%	Zero = 0 ppm nitrogen Mid = 8.4 – 12.6% High = 21%
TOC (as methane)	25A	0-1000 ppm	Zero = 0 ppm nitrogen Low = 250 – 350 ppm Mid = 450 – 550 ppm High = 800 – 900 ppm

APPENDIX C

EXAMPLE TEMPLATES AND CALCULATIONS

AIR HYGIENE

ENGINE TEST - FIELD DATA SHEET

Company:		
Location:		
Date:		
Unit Make and Model:		
Unit Number:		
Serial Number:		
Data Recorded By:		
Tested With AHI Unit(s):	Truck(s):	Trailer(s):
LDEQ Warmup/Cal Req:	On (Day/Time):	Cal (Day/Time):

CYLINDER SERIAL NUMBERS		O_2	NOx	CO	THC	CO_2	SO_2
	Low						
	Mid						
	High						

NO_2 CONVERSION	
NO_2 Gas (ppm)	
NO Reading (ppm)	
NOx Reading (ppm)	
Cylinder Num	

Stack Dia. = ____________

Measured By: ____________

Measured With: ____________

RUN INFORMATION	Run #1	Run #2	Run #3	Run #4	Average
Time Start (hh:mm:ss)					
Time Stop (hh:mm:ss)					
Barometric Pressure (in. Hg)					
Ambient Temperature (°F)					
Relative Humidity (%)					
Suction Pressure (psig)					
Discharge Pressure (psig)					
Rated Horsepower (hp)					
Actual Horsepower (hp)					
Fuel Flow (SCF/hr)					
Turbo Speed (npt) or (rpm)					
Engine Speed (npg) or (rpm)					
Air Manifold Temperature (°F)					
Air Manifold Pressure (psig or in. Hg)					
Engine Timing BTDC					

REPORT INFORMATION	INSTRUMENT	SERIAL #
O_2		
NOx		
CO		
THC		
CO_2		
SO_2		

RESPONSE TIME	TIME (hh:mm)	RESP (min)
Gas Inject	/ /	
1st Inst. @ 95%	/ /	/ /
2nd Inst. @ 95%	/ /	/ /
3rd Inst. @ 95%	/ /	/ /

CALIBRATION	O_2		NOx		CO		THC		CO_2	
	Conc.	Actual	Conc.	Actual	Conc.	Actual	Conc.	Actual	Conc.	Actual
Zero Gas										
Low Gas										
Mid Gas										
High Gas										

BIAS	O_2		NOx		CO		THC		CO_2	
	Zero	Mid	Zero	Mid	Zero	Mid	Zero	Mid	Zero	Mid
Initial/Run #1										
Run #1/Run #2										
Run #2/Run #3										
Run #3/Run #4										
Run #4/Final										
Bias Gas Actual Conc.		______		______		______		______		______

Air Permit # :	
Plant Name or Location:	
Date:	
Project Number:	
Manufacturer & Equipment:	
Model:	
Serial Number:	
Unit Number:	
Test Load:	
Tester(s) / Test Unit(s):	

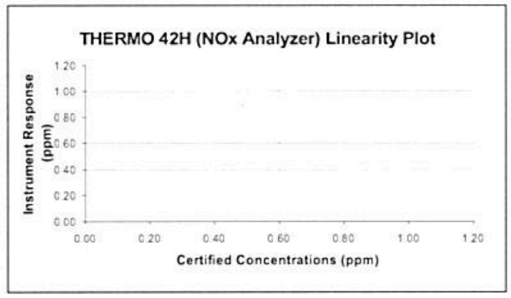
		RUN																	
	UNITS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Start Time	hh:mm:ss																		
End Time	hh:mm:ss																		
Bar. Pressure	in. Hg																		
Amb. Temp.	°F																		
Rel. Humidity	%																		
Spec. Humidity	lb water / lb air																		
Comb. Inlet Pres.	psig																		
NOx Water Inj.	gpm																		
Total Fuel Flow	SCFH																		
Heat Input	MMBtu/hr																		
Power Output	megawatts																		
Steam Rate	lb/hr																		

Calibration Date:

Client:

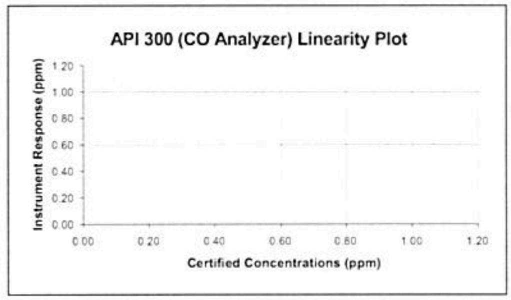
NOx Span (ppm) =

THERMO 42H (NOx Analyzer)				
Certified Concentration (ppm)	Instrument Response (ppm)	Calibration Error (%)	Absolute Conc. (ppm)	Pass or Fail (±2%, ≤0.5ppm)
Linearity =				



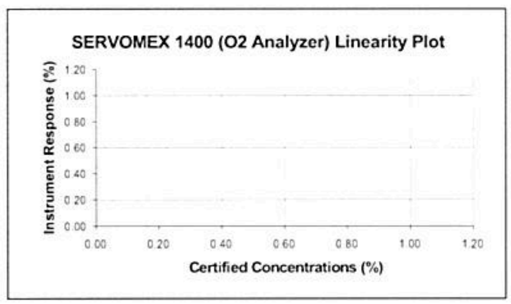
CO Span (ppm) =

API 300 (CO Analyzer)				
Certified Concentration (ppm)	Instrument Response (ppm)	Calibration Error (%)	Absolute Conc. (ppm)	Pass or Fail (±2%, ≤0.5ppm)
Linearity =				



O2 Span (%) =

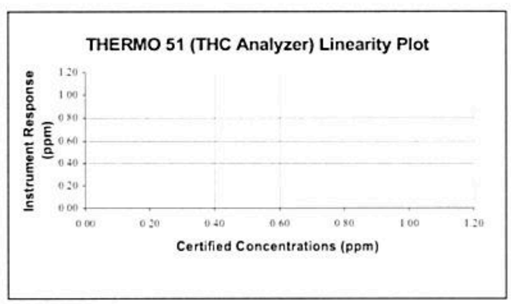
SERVOMEX 1400 (O_2 Analyzer)				
Certified Concentration (ppm)	Instrument Response (ppm)	Calibration Error (%)	Absolute Conc. (ppm)	Pass or Fail (±2%, ≤0.5%)
Linearity =				



THC Range (ppm) =

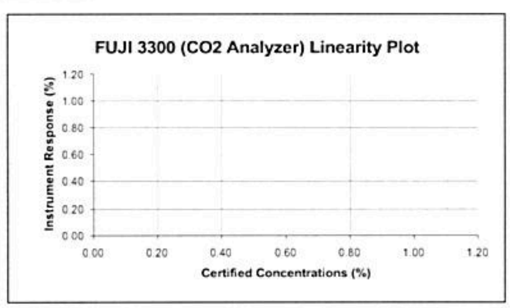
THERMO 51 (THC Analyzer)				
Certified Concentration (ppm)	Instrument Response (ppm)	Calibration Error (%)	Estimated Point (ppm)	Pass or Fail (±2,5%)[1]
Linearity =				

[1]-zero/high based on 2% of span,low/mid based on 5% of concentration



CO2 Span (%) =

FUJI 3300 (CO_2 Analyzer)				
Certified Concentration (ppm)	Instrument Response (ppm)	Calibration Error (%)	Absolute Conc. (ppm)	Pass or Fail (±2%, ≤0.5%)
Linearity =				



Fuel Data

Fuel F_d factor		SCF/MMBtu
Fuel Heating Value (HHV)		Btu/SCF

Weather Data

Barometric Pressure		in. Hg
Relative Humidity		%
Ambient Temperature		°F
Specific Humidity		lb H_2O / lb air

Unit Data

Unit Load		megawatts
Heat Input		lb/MMBtu
Steam Rate		Steam lb/hr
Combustor Inlet Pres.		psig
NOx Control Water Injection		gpm
Est. Stack Moisture		%
Stack Exhaust Flow (M2)		SCFH
Stack Exhaust Flow (M19)		SCFH

Run - 1

Date/Time (mm/dd/yy hh:mm:ss)	Elapsed Time (seconds)	O_2 (%)	NOx (ppmvd)	CO (ppmvd)

RAW AVERAGE

		O_2	NOx	CO
	Serial Number:			
		(%)	(ppmvd)	(ppmvd)
Bias	Initial Zero			
	Final Zero			
	Avg. Zero			
	Initial UpScale			
	Final UpScale			
	Avg. UpScale			

Upscale Cal Gas

EMISSIONS DATA	O_2	NOx	CO
Corrected Raw Average (ppm/% dry basis)			
Corrected Raw Average (ppm/% wet basis)			
Concentration (ppm@ %O_2)			
Concentration (ppm@ %O_2 &ISO)			
Emission Rate (lb/hr)			
Emission Rate (tons/day) at 24 hr/day			
Emission Rate (tons/year) at 8760 hr/yr			
Emission Rate (lb/MMBtu)			
Emission Rate (g/hp*hr)			

DRIFT AND BIAS CHECK			
Run - 1	O2	NOx	CO
Raw Average			
Corrected Average			
Initial Zero			
Final Zero			
Avg. Zero			
Initial UpScale			
Final UpScale			
Avg. UpScale			
Sys Resp (Zero)			
Sys Resp (Upscale)			
Upscale Cal Gas			
Initial Zero Bias			
Final Zero Bias			
Zero Drift			
Initial Upscale Bias			
Final Upscale Bias			
Upscale Drift			
Alternative Specification Abs Diff: Initial Zero			
Final Zero			
Initial Upscale			
Final Upscale			
Calibration Span			
3% of Range (drift)			
5% of Range (bias)			

DRIFT AND BIAS CHECK			
Run - 2	O2	NOx	CO
Raw Average			
Corrected Average			
Initial Zero			
Final Zero			
Avg. Zero			
Initial UpScale			
Final UpScale			
Avg. UpScale			
Sys Resp (Zero)			
Sys Resp (Upscale)			
Upscale Cal Gas			
Initial Zero Bias			
Final Zero Bias			
Zero Drift			
Initial Upscale Bias			
Final Upscale Bias			
Upscale Drift			
Alternative Specification Abs Diff: Initial Zero			
Final Zero			
Initial Upscale			
Final Upscale			
Calibration Span			
3% of Range (drift)			
5% of Range (bias)			

EMISSION CALCULATIONS SUMMARY TABLES

Company:
Engine Tested:
Engine Serial #:

Date:
Location:

Stack Gas Flow Rate: Method 19

Test #	Brake Horsepower	O_2 Conc. (%)	Fuel Heating Value (Btu/SCF)	F Factor-Dry Oxy. (DSCFex/MMBtu)	Fuel Flow (SCF/hr)	Stack Flow (SCF/hr)
1						
2						
3						
Average						

NOx Mass Emission Rate

Test #	Brake Horsepower	NOx Conc. (ppmvd)	MW	E (g/hp*hr)	E (lb/hr)	E (ton/yr)	E (lb/MMBtu)
1			46.01				
2			46.01				
3			46.01				
Average			**46.01**				

CO Mass Emission Rate

Test #	Brake Horsepower	CO Conc. (ppmvd)	MW	E (g/hp*hr)	E (lb/hr)	E (ton/yr)	E (lb/MMBtu)
1			28.00				
2			28.00				
3			28.00				
Average			**28.00**				

Fuel Flow (Btu/hp•hr) is based upon the worst case assumption of 8,500 Btu/hp•hr fuel usage when site data for fuel flow is not available.

TABLE 2.1: ENGINE EMISSIONS REPORT

Test Period:				Air Permit Number:	
Location:				Unit Number:	
Date:				Suction Pressure (psi):	
Project Number:				Discharge Pressure (psi):	
Engine Manufacturer:				Stack Exhaust Temperature (°F):	
Engine Model:				Rated Horsepower (hp):	
Engine Serial Number:				Brake Horsepower (bhp):	
Analyzer Manufacturers:	TECO(NOx), API(CO), TECO(THC)			Engine Fuel Flow (SCFH):	
Analyzer Model Numbers:	42H, 300, 51			Specific Gravity:	
Date Analyzers Calibrated:				Fuel Heating Value [HHV] (Btu/SCF):	
Emission Test Results:	Appendix A			BSFC (Btu/hp*hr):	
Analyzer Data Plots:	Appendix B			Annual Hours Allowed to Operate:	8,760
Cal Gas Spec. Sheets:	Appendix C			Engine Speed (rpm):	
Quality Control Data Sheets:	Appendix D			Air Manifold Temp (°F):	
Chromatograph Report:	Appendix E			Air Manifold Pressure (psi):	
Ambient Temperature (°F):				Turbo Speed (rpm):	
Barometric Pressure (in. Hg):				Engine Ignition Timing (°BTDC):	
Relative Humidity (%):				Load Step:	
				Torque (%):	
				Tested By: Air Hygiene International, Inc.	

Emission Test Results			
Pollutant (units)	Stack Test Results	Permit Limits	Passing
NOx (avg. ppmvd)			
CO (avg. ppmvd)			
VOC (avg. ppmvd)			
NOx @15%O_2 O_2 (avg. ppmvd)			
CO @15%O_2 O_2 (avg. ppmvd)			
VOC @15%O_2 O_2 (avg. ppmvd)			
NOx (avg. lb/hr)			
CO (avg. lb/hr)			
VOC (avg. lb/hr)			
NOx (avg. g/hp*hr)			
CO (avg. g/hp*hr)			
VOC (avg. g/hp*hr)			

All testing conducted according to United States Environmental Protection Agency (EPA), Methods: 7e, 10 and 25a.

EXAMPLE CALCULATIONS (FFACTOR)

RM 19, (07-19-06), 2.0 Summary of Method, 2.1 Emission Rates. Oxygen (O_2) or carbon dioxide (CO_2) concentrations and appropriate F factors (ratios of combustion gas volumes to heat inputs) are used to calculate pollutant emission rates from pollutant co

RM 19, (07-19-06), 12.2 Emission Rates of PM, SO2, and NOx. Select from the following sections the applicable procedure to compute the PM, SO2, or NOx emission rate (E) in lb/MMBtu. The pollutant concentration must be in lb/scf and the F factor must be in scf/MMBtu. If the pollutant concentration (C) is not in the appropriate units, use Table 19–1 in Section 17.0 to make the proper conversion. An F factor is the ratio of the gas volume of the products of combustion to the heat content of the fuel. The dry F factor (F_d) includes all components of combustion less water, the wet F factor (F_w) includes all components of combustion, and the carbon F factor (F_c) includes only carbon dioxide.

Mark's Std Hdbk, 10th ed.,pg 4-26
High Heat Value Dry (HHV_{dry}), calc for Methane (single component for the fuel gas)

$$HHV_{dry}\,(Btu/SCF) = \left[\left(\frac{M_{\%}}{100}\right) \times GCM\right]$$

$HHV_{dry} = \frac{\%}{100.00} \times \frac{Btu}{SCF} = \frac{\quad}{}\frac{Btu}{SCF}$

Mark's Std Hdbk, 10th ed., pg 4-26
Low Heat Value Dry (LHV_{dry}), calc for Methane (single component for the fuel gas)

$$LHV_{dry}\,(Btu/SCF) = \left[\left(\frac{M_{\%}}{100}\right) \times NCM\right]$$

$LHV_{dry} = \frac{\%}{100.00} \times \frac{Btu}{SCF} = \frac{Btu}{SCF}$

Civil Eng. Ref. Man.,7th Ed.,pg 14-9/GPA Ref. Bulletin 181-86, App. C
High Heat Value Wet (HHV_{wet}), calc for entire sample (all components of the fuel gas)

$$HHV_{wet}\,(Btu/SCF) = \frac{HHV_{dry}}{W/D.\,factor}$$

$HHV_{wet} = \frac{Btu/SCF}{} =$ Btu/SCF

Civil Eng. Ref. Man.,7th Ed.,pg 14-9/GPA Ref. Bulletin 181-86, App. C
Low Heat Value Wet (LHV_{wet}), calc for entire sample (all components of the fuel gas)

$$LHV_{wet}\,(Btu/SCF) = \frac{LHV_{dry}}{W/D.\,factor}$$

$LHV_{wet} = \frac{Btu/SCF}{} =$ Btu/SCF

Lbs Component per Lb-Mol of Gas (CM), calc for Methane (single component for the fuel gas)

$$CM\,(lb/lb-mol) = \left[\left(\frac{M_{\%}}{100}\right) \times MW\right]$$

$CM = \frac{\%}{100.00} \times \frac{lb}{lb\text{-}mol} =$ ____ lb/lb-mol

ASTM D 3588
Fuel Molecular Weight (MW_{Fuel})

$$MW_{Fuel}\,(lb/lb\cdot mol) = \left[\sum(CM)\right]$$

$MW_{Fuel} =$ lb/lb-mol
\+ lb/lb-mol
\+ etc. = lb/lb-mol

Btu per Lb of Gas Gross (**GCV**)

$$GCV\,(Btu/lb) = \left[\frac{HHV_{dry} \times G}{MW_{Fuel}}\right]$$

$GCV = \frac{Btu/SCF \times ft^3/lbmol}{lb/lb\text{-}mol} =$ Btu/lb

ASTM D 3588 (SG)
Specific Gravity

$$SG = \left[\frac{MW_{Fuel}}{MW_{AIR}}\right]$$

$SG = \frac{lb/lb\text{-}mol}{28.96\ lb/lb\text{-}mol} =$

Btu per Lb of Gas Net (**NCV**)

$$NCV\,(Btu/lb) = \left[\frac{LHV_{dry} \times G}{MW_{Fuel}}\right]$$

$NCV = \frac{Btu/SCF \times ft^3/lbmol}{lb/lb\text{-}mol} =$ Btu/lb

Weight Percent of Component ($C_{\%}$), methane

$$C_{\%}\,(\%) = \left[\left(\frac{CM}{MW_{Fuel}}\right) \times 100\right]$$

$C_{\%} = \frac{lb/lb\text{-}mol}{lb/lb\text{-}mol} \times 100 =$ %

RM 19, (07-19-06), **Weight Percent of Volatile Organic Compounds** ($VOC_{\%}$)

$$VOC_{\%}\,(\%) = \left[\sum_{C_3H_8}^{C_nH_n} M_{\%}\right]$$

$VOC_{\%} =$ % + % + % + etc. = %

RM 19, (07-19-06), 12.3.2 Determined **F Factors**. If the fuel burned is not listed in Table 19–2 or if the owner or operator chooses to determine an F factor rather than use the values in Table 19–2, use the procedure below: 12.3.2.1 Equations. Use the eq

RM 19, (07-19-6), 12.1 Nomenclature

K (scf/lb)/%

H	3.64
C	1.53
S	0.57
N_2	0.14
O_2	0.46

$$F_d = \frac{K(K_{hd}\%H + K_c\%C + K_s\%S + K_n\%N - K_o\%O)}{GCV} \quad \text{Eq. 19-13}$$

$$F_d = \frac{10^6 Btu}{MMBtu} \times \left[\frac{3.64\ SCF}{lb\cdot\%} \times \ \% + \frac{1.53\ SCF}{lb\cdot\%} \times \ \% + \frac{0.57\ SCF}{lb\cdot\%} \times \ \% + \frac{0.14\ SCF}{lb\cdot\%} \times \ \% - \frac{0.46\ SCF}{lb\cdot\%} \times \ \%\right] \times \frac{lb}{Btu} = \frac{SCF}{MMBtu}$$

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (INFORMATION)

Specific Humidity (RH_{sp})

Note: RHsp (gr/lb) calculated using temperature, relative humidity, and barometric pressure with psychrometric chart, psychrometric calculator, or built in psychrometric algorithm.

$$RH_{sp}(lb/lb) = \left[\left(\frac{gr}{lb}\right) \times \frac{lb}{7000\ gr}\right]$$

$RH_{sp} = \frac{gr}{lb} \times \frac{l\ lb}{7000\ gr} = \frac{lb\ H_2O}{lb\ Air}$

Fuel Flow Conversion (Q_f)

Note: Qf(lb/min) is a value uptained from the source operator.

$$Q_f = \left[Q_f \times G \times \left(\frac{1}{MW_{Fuel}}\right)\right]$$

$Q_f = \frac{lb}{min} \times \frac{60\ min}{hr} \times \frac{ft^3}{lb\text{-}mol} \times \frac{lb\text{-}mol}{lb} =$ SCFH

Combustor Inlet Pressure / Compressor Discharge Pressure (CIP / CDP)
(corrected from gauge to atmospheric pres. and conv. to mm Hg.)

Note: CIP / CDP (psig) is a value obtained from the source operator.

$$CIP / CDP = \left[(psig + P) \times \frac{51.71493\ mmHg}{1 psi}\right]$$

CIP / CDP = (psig +) x $\frac{51.71493\ mmHg}{1\ psia}$ = mmHg (abs)

Heat Rate (MMBtu/hr)

$$HR = \frac{HHV_{DRY} \times Q_f}{1{,}000{,}000}$$

Heat Rate = $\frac{Btu}{SCF} \times \frac{SCF}{hr} \times \frac{MMBtu}{10^6\ Btu} = \frac{MMBtu}{hr}$

Estimated Stack Gas Moisture Content (B_{ws})

$$B_{ws}(\%) = \frac{2 \times Q_f}{Q_s} \times 100$$

$B_{ws} = 2 \times \frac{SCF}{hr} \times \frac{hr}{SCF} \times 100 =$ %

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (CALIBRATION)

Analyzer Calibration Error

RM 7E, (08-15-06), 12.2 Analyzer Calibration Error. For non-dilution systems, use Equation 7E-1 to calculate the analyzer calibration error for the low-, mid-, and high-level calibration gases. (calc for analyzer mid gas, if applicable)

$$ACE = \left(\frac{C_{Dir} - C_V}{CS}\right) \times 100$$ Eq. 7E-1

ACE = $\frac{ppm - \quad ppm}{ppm} \times 100 =$ %

Calibration Error and Estimated Point, RM 25A, THC Analyzer

RM 25A, (07-19-06), 8.4 Calibration Error Test. Immediately prior to the test series (within 2 hours of the start of the test), introduce zero gas and high-level calibration gas at the calibration valve assembly. Adjust the analyzer output to the appropriate levels, if necessary. Calculate the predicted response for the low-level and mid-level gases based on a linear response line between the zero and high-level response. Then introduce low-level and mid-level calibration gases successively to the measurement system. ... These differences must be less than 5 percent of the respective calibration gas value. (calc for THC analyzer mid gas, if applicable)

$$E_P = \frac{C_{Dir(H)} - C_{Dir(Z)}}{C_{V(H)} - C_{V(Z)}} \times C_{Dir(M)} + C_{Dir(Z)}$$ Eq. of a line y=mx+b

$E_p = \frac{ppm - \quad ppm}{ppm - \quad ppm} \times$ ppm + = ppm

$$ACE = \left(\frac{C_{Dir} - C_V}{CS}\right) \times 100$$ Eq. 7E-1

$ACE_{THC} = \frac{ppm - \quad ppm}{ppm} \times 100 =$ %

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (BIAS, DRIFT, AND CORRECTED RAW AVERAGE)

System Bias

RM 7E, (08-15-06), 12.3 System Bias. For non-dilution systems, use Equation 7E-2 to calculate the system bias separately for the low-level and upscale calibration gases. (calc for analyzer upscale gas, Run 1 initial bias, if applicable)

$$SB = \left(\frac{C_S - C_{Dir}}{CS}\right) \times 100$$ Eq. 7E-2

SB = (ppm - ppm) / ppm x 100 = %

Drift Assessment

RM 7E, (08-15-06), 12.5 Drift Assessment. Use Equation 7E-4 to separately calculate the low-level and upscale drift over each test run. (calc for analyzer upscale drift, Run 1, if applicable)

$$D = \left|SB_{final} - SB_i\right|$$ Eq. 7E-4

D = | % - % | = %

Alternative Drift and Bias

RM 7E, (08-15-06), 13.2 / 13.3 System Bias and Drift. Alternatively, the results are acceptable if |Cs – Cdir| is ≤ 0.5 ppmv or if |Cs – Cv| is ≤ 0.5 ppmv (as applicable). (calc for analyzer initial upscale, Run 1, if applicable)

$$SB / D_{Alt} = \left|C_S - C_{Dir}\right|$$ Eq. Section 13.2 and 13.3

SB / D_{Alt} = | ppm - ppm | = ppm

Bias Adjusted Average

RM 7E, (08-15-06), 12.6 Effluent Gas Concentration. For each test run, calculate Cavg, the arithmetic average of all valid concentration values (e.g., 1-minute averages). Then adjust the value of Cavg for bias, using Equation 7E-5. (calc for analyzer, Run 1, if applicable)

$$C_{Gas} = \left(C_{Avg} - C_O\right) \times \left(\frac{C_{MA}}{C_M - C_O}\right)$$ Eq. 7E-5

C_{Gas} = (ppm - ppm) x (ppm / (ppm - ppm)) = ppm

EXAMPLE CALCULATIONS (BSFC)

Using LHV with Q_f (Btu/hp*hr)

$$BSFC\ (Btu / hp \cdot hr) = Q_f$$

BSFC = Btu / hp*hr = Btu / hp*hr

Using HHV with Q_f (SCFH)

$$BSFC\ (Btu / hp \cdot hr) = \frac{HHV \times Q_f}{bhp}$$

BSFC = Btu / SCF x SCF / hr x 1 / hp = Btu / hp*hr

Using LHV with Q_f (SCFH)

$$BSFC\ (Btu / hp \cdot hr) = \frac{LHV \times Q_f}{bhp}$$

BSFC = Btu / SCF x SCF / hr x 1 / hp = Btu / hp*hr

Using HHV with Q_f (Btu/hp*hr)

$$BSFC\ (Btu / hp \cdot hr) = \frac{Q_f \times HHV}{LHV}$$

BSFC = N/A Btu / hp*hr x Btu / SCF x scf / Btu = Btu / hp*hr

EXAMPLE CALCULATIONS (Emissions based on Table 29 values)

Emission Rate (lb/hr)
Q_f (Btu/hp*hr))

$$E(lb / hr) = \frac{E_{g / hp \cdot hr} \times bhp}{453.6}$$

E (lb/hr) = g / hp*hr x lb / 453.6 g x hp = lb / hr

Emission Rate (g/hp-hr)
Q_f (Btu/hp*hr))

$$E(g / hp \cdot hr) = CRA \times Q_f \times FFactor \times MW \times \frac{1}{10^6} \times \frac{1}{10^6} \times \frac{453.6}{G} \times \frac{20.9\%}{20.9\% - CRA_{O_2}}$$

E (g/hp-hr) = ppm x Btu / hp*hr x SCF / MMBtu x lb / lb-mol x 1 parts / 10^6 ppm x 1 MMBtu / 10^6 Btu x 453.6 g / lb x lb-mol / SCF x 20.9% / (20.9% - %) = g / hp*hr

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (RUNS)

Stack Exhaust Flow (Q_S) - RM19

$$Q_S = \left(\frac{FFactor \times Q_f \times HHV}{1{,}000{,}000}\right) \times \left(\frac{20.9\%}{20.9\% - C_{Gas(O2)}}\right)$$

Note: Equation presented in EPA Emission Measurement Center (EMC), Frequently Asked Questions (FAQ) for Method 19

$$Q_S = \frac{SCF}{MMBtu} \times \frac{SCF}{hr} \times \frac{Btu}{SCF} \times \frac{MMBtu}{10^6\ Btu} \times \left[\frac{20.90\%}{20.9\% - \quad \%}\right] = \quad SCFH$$

NO_2 Conversion Efficiency Correction

RM 7E, (02-27-14), 12.8 NO_2 - NO Conversion Efficiency Correction. If desired, calculate the total NOx concentration with a correction for converter efficiency using Equations 7E-8. (calc for non-bias corrected (raw) NOx gas, Run 1, if applicable)

$$NOx_{Corr} = NO + \frac{NOx - NO}{Eff_{NO2}} \times 100 \qquad \text{Eq. 7E-8}$$

$$NOx_{Corr} = \quad ppm + \frac{ppm - \quad ppm}{\%} \times 100 = \quad ppm$$

Moisture Correction

RM 7E, (02-27-14), 12.10 Moisture Correction. Use Equation 7E-10 if your measurements need to be corrected to a dry basis. (calc for analyzer, Run 1, if applicable) Note: Calculations may not match as Run 1 results are typically also bias adjusted

$$C_D = \frac{C_W}{1 - B_{WS}} \qquad \text{Eq. 7E-10}$$

$$C_D = \frac{ppmvw}{1 -} = \quad ppmvd$$

or inversely, $C_W = C_D \times (1 - B_{WS})$

$$C_W = \quad ppmvd \times \left(1 - \quad\right) = \quad ppmvw$$

Diluent-Corrected Pollutant Concentration, O_2 Based

RM 20, (11-26-02), 7.3.1 Correction of Pollutant Concentration Using O_2 Concentration. Calculate the O_2 corrected pollutant concentration, as follows: (calc for gas, Run 1, if applicable) [now contained in applicable Subpart]

$$C_{adj} = C_{Gas(Target)} \times \left(\frac{20.9\% - AdjFactor}{20.9\% - C_{Gas(O2)}}\right) \qquad \text{Eq. 20-4}$$

$$C_{adj} = \quad ppm \times \left(\frac{20.9\% - \quad \%}{20.9\% - \quad \%}\right) =$$

Diluent-Corrected Pollutant Concentration, CO_2 Based

Calculate the CO_2 corrected pollutant concentration, as follows: (calc for gas, Run 1, if applicable)

$$C_{adj} = C_{Gas(Target)} \times \left(\frac{AdjFactor}{C_{Gas(CO2)}}\right)$$

$$C_{adj} = \quad ppm \times \left(\frac{\%}{\%}\right) =$$

Diluent-Corrected Pollutant Concentration, O_2 Based with CO_2 Measurements

RM 20, (11-26-02), 7.3.2 Correction of Pollutant Concentration to Percent O_2 Using CO_2 Concentration. Calculate the O_2 corrected pollutant concentration, as follows: (calc for gas, Run 1, if applicable) [now contained in applicable Subpart]

$$C_{adj} = C_{Gas(Target)} \times \frac{X_{CO2}}{C_{Gas(CO2)}} \qquad \text{Eq. 20-5}$$

$$C_{adj} = \quad ppm \times \frac{\%}{\%} =$$

7.2 CO_2 Correction Factor. If pollutant concentrations are to be corrected to percent O_2 and CO_2 concentration is measured in lieu of O_2 concentration measurement, a CO_2 correction factor is needed. Calculate the CO_2 correction factor as follows: 7.2.1 Calculate the fuel specific F_o, as follows: 7.2.2. Calculate the CO_2 correction factor for correcting measurement data to percent oxygen, as follows:

Eq. 20-2

$$F_o = \frac{0.209\, F_d}{F_c}$$

$$F_o = \frac{0.209 \times \quad SCF/MMBtu}{SCF/MMBtu} =$$

Eq. 20-3

$$X_{CO2} = \frac{20.9\% - AdjFactor}{F_o}$$

$$X_{CO2} = \frac{20.9\% - \quad \%}{} = \quad \%$$

Diluent-Corrected Pollutant Concentration Corrected to ISO Conditions

40CFR60.335(b)(1), Conversion for conc. at ISO Conditions (68°F, 1 atm). Calculate, as follows: (calc for @% with Run 1 data, if applicable)

$$C_{ISO} = C_{Adj} \times \sqrt{\frac{P_r}{P_o}} \times e^{(19 \times (H_O - 0.00633))} \times \left(\frac{288}{T_a}\right)^{1.53}$$

$$C_{ISO} = \quad \times \left(\sqrt{\frac{\dfrac{psig + 14.69232\ psi}{0.01933677\ psi/mm\ Hg.}}{\dfrac{psig + \quad psi}{0.01933677\ psi/mm\ Hg.}}}\right) \times 2.718^{(19 \times (\quad lb/lb - 0.00633))} \times \left(\frac{288\ K}{K}\right)^{1.53} = \quad ppm@\%\ and\ ISO$$

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (RUNS)

Emissions Rate (lb/hr)

Calculation for pound per hour emission rate. Calculate, as follows: (calc for gas Run 1, if applicable)

$$E_{lb/hr} = \frac{C_{Gas}}{10^6} \times \frac{Q_S \times MW}{G}$$

$$E_{lb/hr} = \frac{\text{ppm}}{10^6\ \text{ppm/part}} \text{ x } \frac{\text{SCFH x} \qquad \text{lb/lb-mol}}{\text{SCF/lb-mol}} = \frac{\text{lb}}{\text{hr}}$$

Emissions Rate (ton/year)

Calculation for tons per year emission rate based on 8760 hours per year. Calculate, as follows: (calc for gas Run 1, if applicable)

$$E_{ton/yr} = \frac{E_{lb/hr} \times hr_{year}}{2000}$$

$$E_{ton/yr} = \frac{\text{lb}}{\text{hr}} \text{ x } \frac{\text{hr}}{\text{year}} \text{ x } \frac{\text{ton}}{\text{2000 lb}} = \frac{\text{ton}}{\text{year}}$$

Emissions Rate (lb/MMBtu)

RM 19, (07-19-06), 12.2 Emission Rates of PM, SO2, and NOx. Select from the following sections the applicable procedure to compute the PM, SO2, or NOx emission rate (E) in ng/J (lb/million Btu). (calc for gas Run 1, if applicable)

Oxygen Based

12.2.1 Oxygen-Based F Factor, Dry Basis. When measurements are on a dry basis for both O_2 (%O_2d) and pollutant (Cd) concentrations, use the following equation:

$$E_{lb/MMBtu} = \frac{C_{Gas} \times F_d Factor \times Conv_C \times 20.9\%}{20.9\% - C_{Gas(O2)}} \qquad \text{Eq. 19-1}$$

$$E_{lb/MMBtu} = \frac{\text{ppm x} \qquad \text{SCF/MMBtu x} \qquad \text{lb/ppm*ft}^3 \text{ x } 20.9\%}{20.9\% - \qquad \%} = \frac{\text{lb}}{\text{MMBtu}}$$

Carbon Dioxide Based

12.2.4 Carbon Dioxide-Based F Factor, Dry Basis. When measurements are on a dry basis for both CO_2 (%CO_2d) and pollutant (Cd) concentrations, use the following equation:

$$E_{lb/MMBtu} = \frac{C_{Gas} \times F_d Factor \times Conv_C \times 100\%}{C_{Gas(CO2)}} \qquad \text{Eq. 19-6}$$

$$E_{lb/MMBtu} = \frac{\text{ppm x} \qquad \text{SCF/MMBtu x} \qquad \text{lb/ppm*ft}^3 \text{ x } 100\%}{\%} = \frac{\text{lb}}{\text{MMBtu}}$$

Conversion Constant

Convc for

$$Conv_c(lb/ppm \cdot ft^3) = \frac{\frac{MW}{G}}{10^6}$$

$$Conv_c = \frac{\frac{\text{lb}}{\text{lb•mole}} \text{ x } \frac{\text{lb•mole}}{\text{SCF}}}{10^6} = \frac{\text{lb}}{\text{ppm-ft}^3}$$

Sulfur Dioxide Rate (lb/MMBtu), 40CFR60, App. A, RM 19, Eq. 19-25 (11/20/03)

$$SO_2(lb/MMBtu) = 0.97 \times K \times \frac{S(wt\%)}{GCV}$$

$$SO_2 = 0.97 \text{ x } \frac{2\text{x}10^4 \text{ Btu}}{\text{wt\%•MMBtu}} \text{ x } \frac{\text{wt\%}}{\text{Btu/lb}} = \frac{\text{lb}}{\text{MMBtu}}$$

Emissions Rate (g/hp-hr)

Calculation for grams per horsepower-hour. Calculate, as follows: (calc for gas Run 1, if applicable)

$$E_{g/hp\,hr} = \frac{E_{lb/hr} \times 453.6}{mw \times 1341.022} \ or \ \frac{E_{lb/hr} \times 453.6}{hp}$$

$$E_{g/hp\text{-}hr} = \frac{\text{lb}}{\text{hr}} \text{ x } \frac{\text{453.6 g}}{\text{lb}} \text{ x } \frac{1}{\text{mw}} \text{ x } \frac{\text{mw}}{\text{1341.022 hp}} = \frac{\text{g}}{\text{hp*hr}}$$

$$E_{g/hp\text{-}hr} = \frac{\text{lb}}{\text{hr}} \text{ x } \frac{\text{453.6 g}}{\text{lb}} \text{ x } \frac{1}{\text{hp}} = \frac{\text{g}}{\text{hp*hr}}$$

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (FTIR SPIKE)

Concentration to dilute by 90% (ppmvw)

$$AVG_d = \frac{AVG_r}{2}$$

AVG$_d$ = $\frac{\quad\text{ppmvw}}{2}$ = ppmvw

Ideal matrix spike yield (ppmvw)

$$Y_{ideal} = AVG_d \times \left(\frac{Q_m}{Q_{sys}}\right) + AVG_r \times \left(1 - \frac{Q_m}{Q_{sys}}\right)$$

Y_{ideal} = ppmvw x $\left(\frac{\text{lpm}}{\text{lpm}}\right)$ + ppmvw x $\left(1 - \frac{\text{lpm}}{\text{lpm}}\right)$ = ppmvw

Minimum matrix spike yield (ppmvw)

$$Y_{min} = Y_{ideal} \times 0.7$$

Y_{ideal} = ppmvw x 0.7 = ppmvw

Maximum matrix spike yield (ppmvw)

$$Y_{max} = Y_{ideal} \times 1.3$$

Y_{ideal} = ppmvw x 1.3 = ppmvw

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

RM 7E, (08-15-06), 12.1 Nomenclature. The terms used in the equations are defined as follows:

ACE = Analyzer calibration error, percent of calibration span.
B_{WS} = Moisture content of sample gas as measured by Method 4 or other approved method, percent/100.
C_{Avg} = Average unadjusted gas concentration indicated by data recorder for the test run.
C_D = Pollutant concentration adjusted to dry conditions.
C_{Dir} = Measured concentration of a calibration gas (low, mid, or high) when introduced in direct calibration mode.
C_{Gas} = Average effluent gas concentration adjusted for bias.
C_M = Average of initial and final system calibration bias (or 2-point system calibration error) check responses for the upscale calibration gas.
C_{MA} = Actual concentration of the upscale calibration gas, ppmv.
C_O = Average of the initial and final system calibration bias (or 2-point system calibration error) check responses from the low-level (or zero) calibration gas.
C_S = Measured concentration of a calibration gas (low, mid, or high) when introduced in system calibration mode.
C_{SS} = Concentration of NOx measured in the spiked sample.
C_{Spike} = Concentration of NOx in the undiluted spike gas.
C_{Calc} = Calculated concentration of NOx in the spike gas diluted in the sample.
C_V = Manufacturer certified concentration of a calibration gas (low, mid, or high).
C_W = Pollutant concentration measured under moist sample conditions, wet basis.
CS = Calibration span.
D = Drift assessment, percent of calibration span.
E_p = The predicted response for the low-level and mid-level gases based on a linear response line between the zero and high-level response.
Eff_{NO2} = NO_2 to NO converter efficiency, percent.
H = High calibration gas, designator.
L = Low calibration gas, designator.
M = Mid calibration gas, designator.
NOFinal = The average NO concentration observed with the analyzer in the NO mode during the converter efficiency test in Section 16.2.2.
NOxCorr = The NOx concentration corrected for the converter efficiency.
NOxFinal = The final NOx concentration observed during the converter efficiency test in Section 16.2.2.
NOxPeak = The highest NOx concentration observed during the converter efficiency test in Section 16.2.2.
Q_{Spike} = Flow rate of spike gas introduced in system calibration mode, L/min.
Q_{Total} = Total sample flow rate during the spike test, L/min.
R = Spike recovery, percent.
SB = System bias, percent of calibration span.
SB_i = Pre-run system bias, percent of calibration span.
SB_f = Post-run system bias, percent of calibration span.
SB / D_{Alt} = Alternative absolute difference criteria to pass bias and/or drift checks.
SCE = System calibration error, percent of calibration span.
SCE_i = Pre-run system calibration error, percent of calibration span.
SCE_{final} = Post-run system calibration error, percent of calibration span.
Z = Zero calibration gas, designator.

40CFR60.355(b)(1), (09-20-06), Nomenclature. The terms used in the equations are defined as follows:

P_r = reference combustor inlet absolute pressure at 101.3 kilopascals ambient pressure, mm Hg
P_o = observed combustor inlet absolute pressure at test, mm Hg
H_o = observed humidity of ambient air, g H_2O/g air
e = transcendental constant, 2.718
T_a = ambient temperature, K

Small Engine and FTIR Nomenclature. The terms used in the equations are defined as follows:

bhp = brake horsepower
hp = horsepower
Q_{sys} = system flow (lpm)
Q_m = matrix spike flow (lpm)

RM 19, (07-29-06), 12.1 Nomenclature. The terms used in the equations are defined as follows:

AdjFactor = percent oxygen or carbon dioxide adjustment applied to a target polltant

B_{wa} = Moisture fraction of ambient air, percent.

Btu = British thermal unit

$\%_C$ = Concentration of carbon from an ultimate analysis of fuel, weight percent.

$\%_{CO2d}$, $\%_{CO2w}$ = Concentration of carbon dioxide on a dry and wet basis, respectively, percent.

CIP / CDP = Combustor inlet pressure / compressor discharge pressure (mm Hg); note, some manufactures reference as PCD.

E = Pollutant emission rate, ng/J (lb/million Btu).

E_a = Average pollutant rate for the specified performance test period, ng/J (lb/million Btu).

E_{ao}, E_{ai} = Average pollutant rate of the control device, outlet and inlet, respectively, for the performance test period, ng/J (lb/million Btu).

E_b = Pollutant rate from the steam generating unit, ng/J (lb/million Btu).

E_{bo} = Pollutant emission rate from the steam generating unit, ng/J (lb/million Btu).

E_c = Pollutant rate in combined effluent, ng/J (lb/million Btu).

E_{co} = Pollutant emission rate in combined effluent, ng/J (lb/million Btu).

E_d = Average pollutant rate for each sampling period (e.g.,24-hr Method 6B sample or 24-hr fuel sample) or for each fuel lot (e.g., amount of fuel bunkered), ng/J (lb/million Btu).

E_{di} = Average inlet SO_2 rate for each sampling period d, ng/J (lb/million Btu).

E_g = Pollutant rate from gas turbine, ng/J (lb/million Btu).

E_{ga} = Daily geometric average pollutant rate, ng/J (lbs/million Btu) or ppm corrected to 7 percent O_2.

E_{jo},E_{ji} = Matched pair hourly arithmetic average pollutant rate, outlet and inlet, respectively, ng/J (lb/million Btu) or ppm corrected to 7 percent O_2.

E_h = Hourly average pollutant, ng/J (lb/million Btu).

E_{hj} = Hourly arithmetic average pollutant rate for hour "j," ng/J (lb/million Btu) or ppm corrected to 7 percent O_2.

EXP = Natural logarithmic base (2.718) raised to the value enclosed by brackets.

Fc = Ratio of the volume of carbon dioxide produced to the gross calorific value of the fuel from Method 19

F_d, F_w, F_c = Volumes of combustion components per unit of heat content, scm/J (scf/million Btu).

ft^3 = cubic feet

G = ideal gas conversion factor

(385.23 SCF/lb-mol at 68 deg F & 14.696 psia)

GCM = gross Btu per SCF (constant, compound based)

GCV = Gross calorific value of the fuel consistent with the ultimate analysis, kJ/kg (Btu/lb).

GCV_p, GCV_r = Gross calorific value for the product and raw fuel lots, respectively, dry basis, kJ/kg (Btu/lb).

$\%_H$ = Concentration of hydrogen from an ultimate analysis of fuel, weight percent.

H_b = Heat input rate to the steam generating unit from fuels fired in the steam generating unit, J/hr (million Btu/hr).

H_g = Heat input rate to gas turbine from all fuels fired in the gas turbine, J/hr (million Btu/hr).

$\%_{H2O}$ = Concentration of water from an ultimate analysis of fuel, weight percent.

H_r = Total numbers of hours in the performance test period (e.g., 720 hours for 30-day performance test period).

K = volume of combustion component per pound of component (constant)

K = Conversion factor, 10^{-5} (kJ/J)/(%) [10^6 Btu/million Btu].

K_c = (9.57 scm/kg)/% [(1.53 scf/lb)/%].

K_{cc} = (2.0 scm/kg)/% [(0.321 scf/lb)/%].

K_{hd} = (22.7 scm/kg)/% [(3.64 scf/lb)/%].

K_{hw} = (34.74 scm/kg)/% [(5.57 scf/lb)/%].

K_n = (0.86 scm/kg)/% [(0.14 scf/lb)/%].

K_o = (2.85 scm/kg)/% [(0.46 scf/lb)/%].

K_s = (3.54 scm/kg)/% [(0.57 scf/lb)/%].

K_{sulfur} = $2x10^4$ Btu/wt%-MMBtu

K_w = (1.30 scm/kg)/% [(0.21 scf/lb)/%].

lb = pound

ln = Natural log of indicated value.

L_p,L_r = Weight of the product and raw fuel lots, respectively, metric ton (ton).

$\%_N$ = Concentration of nitrogen from an ultimate analysis of fuel, weight percent.

$M_{\%}$ = mole percent

mol = mole

MW = molecular weight (lb/lb-mol)

MW_{AIR} = molecular weight of air (28.9625 lb/lb-mole)[1]

NCM = net Btu per SCF (constant based on compound)

$\%_O$ = Concentration of oxygen from an ultimate analysis of fuel, weight percent.

$\%_{O2d}$, $\%_{O2w}$ = Concentration of oxygen on a dry and wet basis, respectively, percent.

P_B = barometirc pressure, in Hg

P_s = Potential SO2 emissions, percent.

$\%_S$ = Sulfur content of as-fired fuel lot, dry basis, weight percent.

S_e = Standard deviation of the hourly average pollutant rates for each performance test period, ng/J (lb/million Btu).

$\%_{SI}$ = Concentration of sulfur from an ultimate analysis of fuel, weight percent.

S(wt%) = weight percent of sulfur, per lab analysis by appropriate ASTM standard

S_i = Standard deviation of the hourly average inlet pollutant rates for each performance test period, ng/J (lb/million Btu).

S_o = Standard deviation of the hourly average emission rates for each performance test period, ng/J (lb/million Btu).

$\%S_p$, $\%S_r$ = Sulfur content of the product and raw fuel lots respectively, dry basis, weight percent.

SCF = standard cubic feet

SH = specific humidity, pounds of water per pound of air

$t_{0.95}$ = Values shown in Table 19-3 for the indicated number of data points n.

T_{amb} = ambient temperature, $^{\circ}F$

W/D Factor = 1.0236 = conv. at 14.696 psia and

68 deg F (ref. Civil Eng. Ref. Manual, 7th Ed.)

X_{CO2}=CO_2 Correction factor, percent.

X_k = Fraction of total heat input from each type of fuel k.

Calculations, Formulas, and Constants

The following information supports the spreadsheets for this testing project.

Given Data:

Ideal Gas Conversion Factor = 385.23 SCF/lb-mol at 68 deg F & 14.696 psia

Fuel Heating Value is based upon Air Hygiene's fuel gas calculation sheet. All calculations are based upon a correction to 68 deg F & 14.696 psia

High Heating Values (HHV) are used for the Fuel Heating Value, F-Factor, and Fuel Flow Data per EPA requirements.

ASTM D 3588

Molecular Weight of NOx (lb/lb-mole) =	46.01
Molecular Weight of CO (lb/lb-mole) =	28.00
Molecular Weight of SO2 (lb/lb-mole) =	64.00
Molecular Weight of THC (propane) (lb/lb-mole) =	44.00
Molecular Weight of VOC (methane) (lb/lb-mole) =	16.00
Molecular Weight of NH3 (lb/lb-mole) =	17.03
Molecular Weight of HCHO (lb/lb-mole) =	30.03

40CFR60, App. A., RM 19, Table 19-1

Conversion Constant for NOx =	0.0000001194351
Conversion Constant for CO =	0.0000000726839
Conversion Constant for SO2 =	0.0000001661345
Conversion Constant for THC =	0.0000001142175
Conversion Constant for VOC (methane) =	0.0000000415336
Conversion Constant for NH_3 =	0.0000000442074
Conversion Constant for HCHO =	0.0000000779534

NOTE: units are lb/ppm*ft^3

Formulas:

1. Corrected Raw Average (C_{Gas}), 40CFR60, App. A, RM 7E, Eq. 7E-5 (08/15/06)

$$C_{Gas} = \left(C_{Avg} - C_O\right) \times \left(\frac{C_{MA}}{C_M - C_O}\right)$$

2. Correction to % O_2, 40CFR60, App. A, RM 20, Eq. 20-5 (11/26/02)

$$C_{adj} = C_{Gas\,(Target)} \times \left(\frac{20.9\% - AdjFactor}{20.9\% - C_{Gas\,(O2)}}\right)$$

3. Emission Rate in lb/hr

$$E_{lb/hr} = \frac{C_{Gas}}{10^6} \times \frac{Q_S \times MW}{G}$$

4. Emission Concentration in lb/MMBtu (O_2 based)

$$E_{lb/MMBtu} = \frac{C_{Gas} \times F_d Factor \times Conv_C \times 20.9\%}{20.9\% - C_{Gas\,(O2)}}$$

5. Emission Concentration in lb/MMBtu (CO_2 based)

$$E_{lb/MMBtu} = \frac{C_{Gas} \times F_d Factor \times Conv_C \times 100\%}{C_{Gas\,(CO2)}}$$

RATA SHEET CALCULATIONS

d = Reference Method Data - CEMS Data

S_d = Standard Deviation

CC = Confident Coefficient

n = number of runs

$t_{0.025}$ = 2.5 percent confidence coefficent T-values

RA = relative accuracy

ARA = alternative relative accuracy

BAF = Bias adjustment factor

n	t	n	t	n	t
2	12.706	7	2.447	12	2.201
3	4.303	8	2.365	13	2.179
4	3.182	9	2.306	14	2.160
5	2.776	10	2.262	15	2.145
6	2.571	11	2.228	16	2.131

1. Difference

$$d = \sum_{i=1}^{n} d_i$$

2. Standard Deviation

$$S_d = \sqrt{\frac{\sum_{i=1}^{n} d_i^2 - \left[\frac{\left(\sum_{i=1}^{n} d_i\right)^2}{n}\right]}{n-1}}$$

3. Confident Coefficient

$$CC = t_{0.025} \times \frac{S_d}{\sqrt{n}}$$

4. Relative Accuracy

$$RA = \frac{|d_{AVG}| + |CC|}{RM_{AVG}} \times 100$$

5. Alternative Relative Accuracy

$$ARA = \frac{|d_{AVG}| + |CC|}{AS} \times 100$$

5. Bias Adjustment Factor

$$BAF = 1 + \left(\frac{|d_{AVG}|}{CEM_{AVG}}\right)$$

APPENDIX D

STATEMENT OF QUALIFICATIONS

AIR HYGIENE E'MISSION Statement:
AIR HYGIENE's core philosophy of "**Second-to-None (2-2-0)**", demands extra mile customer service anchored on dignified character and family-oriented principles to deliver unmatched quality stack testing, worth paying for every time. We utilize revolutionary technology and AIR HYGIENE UNIVERSITY to create the best educated work force to define the future of stack testing.

STATEMENT OF QUALIFICATIONS

AIR HYGIENE

AIR EMISSION TESTING SERVICES
January, 2019

INTRODUCTION
AIR HYGIENE INTERNATIONAL, INC. (AIR HYGIENE) is a professional air emission testing services firm operating from corporate headquarters in Broken Arrow, Oklahoma for 20 years. Additional field offices with ready for field use testing labs are strategically located in Las Vegas, Nevada; Austin and Ft. Worth, Texas; Shreveport, Louisiana; Chicago, Illinois; and Pittsburgh, Pennsylvania to serve all fifty (50) United States, Mexico, and Canada. AIR HYGIENE specializes in air emission testing services for combustion sources burning multiple fuels with multiple control devices and supporting equipment.

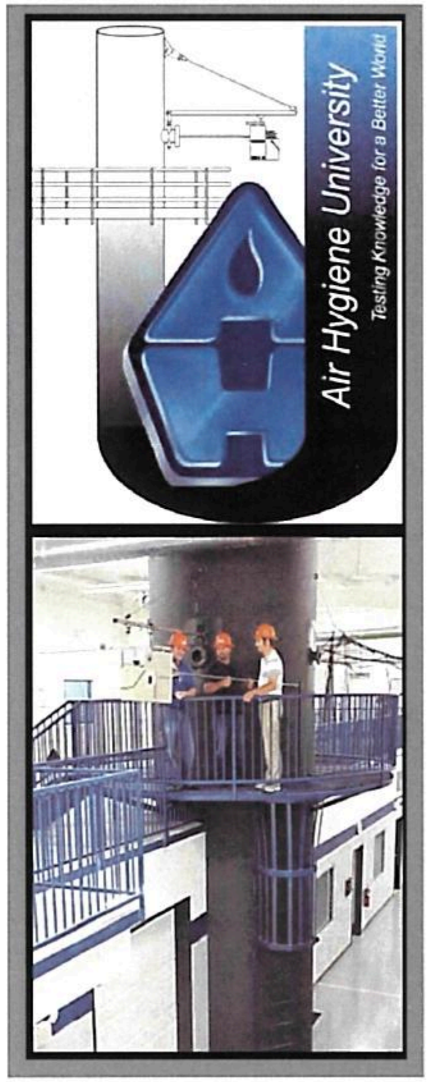
AIR HYGIENE testing laboratories are equipped with the following capabilities:
1. State-of-the-Art air emission analyzers, computers, and data-logging software!
2. Dual racks for multiple source testing simultaneously or multiple points on a single source (in/out SCR, etc.)!
3. NIST traceable gases for the most accurate calibration. Ranges as low as five (5) ppm!
4. PM_{10}, NH_3, mercury (Hg), sulfuric acid mist (H_2SO_4), SO_3, and formaldehyde sampling equipment!
5. VOC testing with on-board gas chromatograph to remove methane and ethane!
6. On-board printers to provide hard copies of testing information on-site!
7. Networking capabilities to provide real-time emission data directly into the control room!

AIR HYGIENE is known for providing professional services which include the following:
- Superior cost effective services to our clients!
- Educated work force trained to utilize the latest in revolutionary technology!
- Meeting our client's needs whether it is 24 hour a day testing or short notice mobilization!
- Using great equipment that is maintained and dependable!
- Understanding the unique start-up and operational needs associated with combustion sources!
- Experience working with state and federal regulations and agencies in all 50 states!

OUR MISSION
Our mission is to provide innovative, practical, top-quality services allowing our clients to increase operating efficiency, save money, and comply with federal and state requirements. We believe our first responsibility is to the client. In providing our unique services, the owners of AIR HYGIENE demand ethical conduct from each employee of the company. The character and integrity of AIR HYGIENE employees allows our clients to feel confident in the air testing services of AIR HYGIENE. Through a long-term commitment to this mission, AIR HYGIENE is known as a company committed to improving our clients' operations.

TESTING EXPERIENCE

AIR HYGIENE has **twenty-six (26) QSTI certified** personnel on staff and more than two hundred (200) years of combined testing experience. We have completed over 25,000 emission tests and our testing services history includes interaction with all 50 state agencies and EPA regional offices. **AIR HYGIENE** testing personnel are rigorously trained through our very own **AIR HYGIENE UNIVERSITY** on EPA reference test methods from 40 CFR Part 51, 60, 63, and 75 along with ASTM methods. All testing personnel are instructed and tested on test responsibilities and must complete a "Demonstration of Capability" test per the **AIR HYGIENE** Quality Assurance Manual and the **AIR HYGIENE** Emission Testing Standard OperatingProcedures Handbook.



AIR HYGIENE has completed testing on over 500 power plants including in excess of 2,500 combustion turbines and 100 coal fired boilers 250,000 megawatts (MW). ***Let us add your project to our list of satisfied customers!***

TESTING SUCCESS STORIES

AIR HYGIENE personnel have performed thousands of testing projects which have yielded significant benefits for our clients. The following project descriptions briefly discuss some of these emission testing projects.

- Conducted Mercury (Hg), PM, selected metals, HCl, Chlorine, and gas testing to verify status with the industrial boiler MACT on six coal fired units at three (3) locations.
- Conducted inlet/outlet baghouse emission testing for Mercury (Hg) to determine control efficiency using Ontario-Hyrdo testing methodology.
- Conducted numerous projects optimizing SCR performance by conducting inlet & outlet SCR analysis for NH_3, NO_x, flow, and Oxygen. Used information to assist with flow optimization and AIG tuning.
- Conducted federal and state required compliance testing for NO_x, CO, PM-10 (front & back-half), SO_2, VOC, Ammonia, Formaldehyde, Opacity, RATA testing (NO_x and CO) for new and updated power plants with both simple and combined cycle turbines firing natural gas and fuel oil.
- Conducted dry low NO_x burner tuning and performance testing for various models of GE, Siemens Westinghouse, Mitsubishi, Pratt & Whitney, and ABB combustion turbines to verify manufacturer's emission guarantees for clients in preparation for compliance testing.
- Performed power plant emission testing for natural gas & fuel oil fired combustion turbines. Tests included federal required testing per 40 CFR Part 75, state air permit requirements, RATA testing, and emission testing to verify manufacturer's guarantees during electric/heat output performance testing.

TESTING LOCATIONS

AIR HYGIENE bases mobilization charges on the distance from your site to the closest of seven (7) regional starting points covering all 50 United States. These include Broken Arrow, Las Vegas, Austin, Ft. Worth, Shreveport, Chicago and Pittsburgh.

Each start point is located such that the **AIR HYGIENE** test teams can mobilize to your site within 24 hours at affordable costs to ensure we are price competitive to any U.S. location.

QUALITY ASSURANCE PROGRAM SUMMARY

AIR HYGIENE has received interim accreditation from the Source Testing Accreditation Council (STAC) per ASTM D7036 as an Air Emission Testing Body (AETB). Air Hygiene also maintains current accreditation from LDEQ, CARB, SCAQMD, and PADEP.

AIR HYGIENE has **twenty-six (26) Qualified Stack Testing Individuals (QSTI)** on staff providing testing leadership for every testing project; including a PhD Chemical Engineer who is ACS Certified managing in house laboratory operations and specialty remote wet chemistry projects.

AIR HYGIENE ensures the quality and validity of its emission measurement and reporting procedures through a rigorous quality assurance (QA) program. The program is developed and administered by an internal QA team and encompasses five major areas:

1. QA reviews of reports, laboratory work, and field testing;
2. Equipment calibration and maintenance;
3. Chain-of-custody;
4. Training; and
5. Knowledge of current test methods.

QA Reviews

AIR HYGIENE'S review procedure includes review of each source test report, along with laboratory and fieldwork, by the QA Team. The most important review is the one that takes place before a test program begins. The QA Team works closely with technical division personnel to prepare and review test protocols. Test protocol review includes selection of appropriate test procedures, evaluation of interferences or other restrictions that might preclude use of standard test procedures, and evaluation and/or development of alternate procedures.

Equipment Calibration and Maintenance

The equipment used to conduct the emission measurements is maintained according to the manufacturer's instructions to ensure proper operation. In addition to the maintenance program, calibrations are carried out on each measurement device according to the schedule outlined by the Environmental Protection Agency. Quality control checks are also conducted in the field for each test program. Finally, AIR HYGIENE participates in a PT gas program by analyzing blind gases semi-annually to ensure continued quality.

Chain-of-Custody

AIR HYGIENE maintains full chain-of-custody documentation on all samples and data sheets. In addition to normal documentation of changes between field sample custodians, laboratory personnel, and field test personnel, AIR HYGIENE documents every individual who handles any test component in the field (e.g., probe wash, impinger loading and recovery, filter loading and recovery, etc.). Samples are stored in a locked area to which only AIR HYGIENE personnel have access. Field data sheets are secured at AIR HYGIENE'S offices upon return from the field.

Training

Training available to both employees and customers through our very own AIR HYGIENE UNIVERSITY is essential to ensure quality testing. Constantly striving to be recognized globally as the worldwide leader in Stack Testing Training, AIR HYGIENE UNIVERSITY has developed a baseline foundation and curriculum using a unique indoor training facility, practice stack, and over 16 years of real-world field testing experience. AIR HYGIENE UNIVERSITY'S classwork combines customized training modules focusing on presentation, testing, resource utilization, and hands-on experience and the knowledge from each module can be combined to provide a final capstone, a Demonstration of Competency in the subject matter of interest. Participants are prepared to pass the Qualified Individual examinations and obtain Federal certifications and have the ability to apply new and refreshed knowledge about each test method to everyday work practices.

Knowledge of Current Test Methods

With the constant updating of standard test methods and the wide variety of emerging test procedures, it is essential that any qualified source tester keep abreast of new developments. AIR HYGIENE subscribes to services, which provide updates on EPA reference methods, rules, and regulations. Additionally, source test personnel regularly attend and present papers at testing and emission-related seminars and conferences.

TESTING QUALITY ASSURANCE ACTIVITIES

A number of quality assurance activities are undertaken before, during, and after turbine testing projects. This section describes each of those activities.

Each instrument's response is checked and adjusted in the field prior to the collection of data via multi-point calibration. The instrument's linearity is checked by first adjusting its zero and span responses to zero nitrogen and an upscale calibration gas in the range of the expected concentrations. The instrument response is then challenged with other calibration gases of known concentration and accepted as being linear if the response of the other calibration gases agreed within ± two percent of range of the predicted values.

NO_2 to NO conversion is checked via direct connect with an EPA Protocol certified concentration of NO_2 in a balance of nitrogen. Conversion is verified to be above 90 percent.

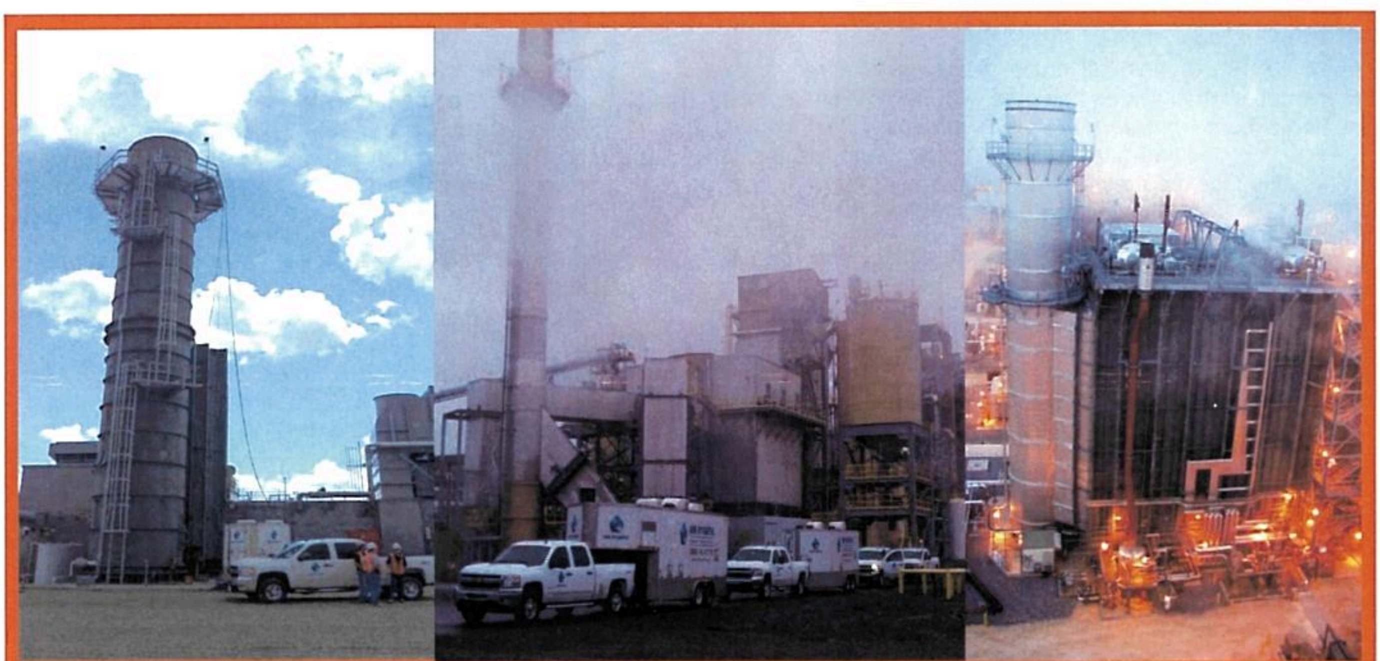
Instruments are both factory- tested and periodically field challenged with interference gases to verify the instruments have less than a two percent interference from CO_2, SO_2, CO, NO, and O_2.

After each test run, the analyzers are checked for zero and span drift. This allows each test run to be bracketed by calibrations and documents the precision of the data collected. The criterion for acceptable data is that the instrument drift is no more than three percent of the full-scale response. Quality assurance worksheets summarize all multipoint calibration linearity checks and the zero to span checks performed during the tests are included in the test report.

The sampling systems is leak checked by demonstrating that a vacuum greater than 10 in. Hg can be held for at least one minute with a decline of less than 1 in. Hg. A leak test is conducted after the sample system is set up and before the system is dismantled. This test is conducted to ensure that ambient air does not dilute the sample. Any leakage detected prior to the tests is repaired and another leak check conducted before testing will commence.

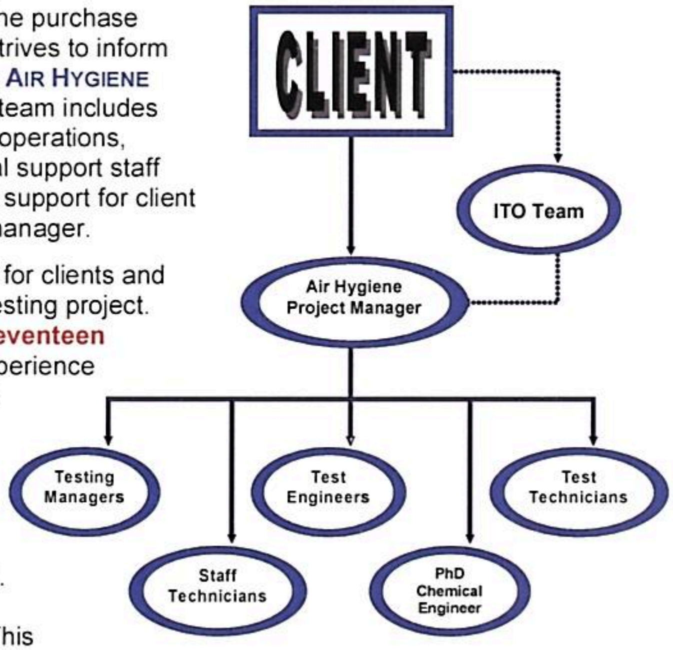
The absence of leaks in the sampling system is also verified by a sampling system bias check. The sampling system's integrity is tested by comparing the responses of the analyzers to the responses of the calibration gases introduced via two paths. The first path is directly into the analyzers and the second path includes the complete sample system with injection at the sample probe. Any difference in the instrument responses by these two methods is attributed to sampling system bias or leakage. The criterion for acceptance is agreement within five percent of the span of the analyzer.

The control gases used to calibrate the instruments are analyzed and certified by the compressed gas vendors to ± one percent accuracy for all gases. EPA Protocol No.1 is used, where applicable, to assign the concentration values traceable to the National Institute of Standards and Technology (NIST), Standard Reference Materials (SRM). The gas calibration sheets as prepared by the vendor are included in the test report.



EMISSION TESTING TEAM

Air Hygiene International, Inc. (AIR HYGIENE) intends to exceed your expectations on every project. From project management to field-testing teams, we're committed to working hard on your behalf. The job descriptions and flow chart below outline AIR HYGIENE's client management strategy for your testing services.



From the initial request through receipt of the purchase order, the Inquisition to Order (ITO) team strives to inform every client of the benefits gained by using AIR HYGIENE for their emission testing project. The ITO team includes representatives from the sales, marketing, operations, and contracts divisions. In addition, several support staff assist to ensure the ITO team provides the support for client needs as requested by a client or project manager.

Project Managers are the primary contact for clients and ultimately responsible for every emission testing project. AIR HYGIENE's Project Managers include **seventeen (17) QSTI certified** testing experts with experience ranging from those with a masters level, to professional engineers to industry experts with over 25,000 testing projects completed. Each project is assigned a Project Manager based primarily upon geographic location, industry experience, contact history, and availability. The Project Manager prepares the testing strategy and organization for the project. This includes preparation of testing protocol; coordination with state agencies, client representatives, and any interested third parties. The site testing and report preparation are executed under the direction of the Project Manager from start to finish.

Testing Managers have completed Air Hygiene's rigorous demonstration of capability training program and are capable of operating all testing equipment and performing all test methods required for your testing project. Testing Managers assist Project Managers by leading the field testing when required, preparing draft reports, calibrating equipment, and overseeing the testing team on-site. AIR HYGIENE's staff includes **seven (7) QSTI certified** testing managers.

Test Engineers have significant background and understanding of emission testing or related services. Test Engineers prepare pre-test drawings for port location, ensure on-site logistics for electrical and mechanical/structural needs, and conduct on-site testing as directed by the Project Manager and/or Testing Manager. Test Engineers often have special understanding of process and/or regulations applicable to specific testing jobs, which provide great value to both the client and Project Manager in testing strategies. AIR HYGIENE's staff includes **two (2) QSTI certified** testing managers.

Test Technicians experience ranges from new hire with technical degree and experience to technicians who have performed 500 emission tests. All test technicians have a basic understanding of emission training and are involved in daily training and under supervision to continue to develop testing skills. Each has testing experience with AIR HYGIENE equipment along with a variety of industries and source equipment. Test Technicians may operate isokinetic sampling trains or gas analyzers on-site under the direction of the Project Manager and assist with preparation of field reports and quality assurance procedures.

Staff Technicians are entry-level personnel who have performed fewer than 500 emission tests. Staff Technicians perform pre-test equipment preparation, on-site test preparation, and testing assistance under the direction of Project Manager and/or Testing Manager. Staff Technicians connect sampling probes to ports, raise and lower equipment to and from sampling platform, and other support activities under the direction of the Project Manager and/or Testing Manager.

PhD Chemical Engineer/Lab Manager our in house, ACS Certified Lab Manager manages in house laboratory operations and is available for specialty remote wet chemistry projects on site to provide added expertise and accuracy.

Accredited Laboratory

A2LA has accredited

AIR HYGIENE INTERNATIONAL, INC.

Broken Arrow, OK

for technical competence in the field of

Environmental Testing

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2005 *General requirements for the competence of testing and calibration laboratories*. This laboratory also meets the R219 – Specific Requirements – TNI Field Sampling and Measurement Organization Accreditation Program. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (*refer to joint ISO-ILAC-IAF Communiqué dated 8 January 2009*).

Presented this 10th day of October 2017

President and CEO
For the Accreditation Council
Certificate Number 3796.01
Valid to August 31, 2019

For the types of tests to which this accreditation applies, please refer to the laboratory's Environmental Scope of Accreditation.

STAC
STACK TESTING ACCREDITATION COUNCIL

American Association for Laboratory Accreditation

Accredited Air Emission Testing Body

A2LA has accredited

AIR HYGIENE INTERNATIONAL, INC.

In recognition of the successful completion of the joint A2LA and Stack Testing Accreditation Council (STAC) evaluation process, this laboratory is accredited to perform testing activities in compliance with ASTM D7036:2004 - Standard Practice for Competence of Air Emission Testing Bodies.

Presented this 10th day of October 2017

President and CEO
For the Accreditation Council
Certificate Number 3796.02
Valid to August 31, 2019

This accreditation program is not included under the A2LA ILAC Mutual Recognition Arrangement.

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